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QUATERNARY PALEONTOLOGY AND PALEOECOLOGY OF CRYSTAL BALL CAVE, MILLARD COUNTY, UTAH: WITH EMPHASIS ON MAMMALS AND DESCRIPTION OF A NEW SPECIES OF FOSSIL SKUNK

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ABSTRACT.— Crystal Ball Cave is located in a small outlier of the Snake Range in Snake Valley 1.7 km (1 mile) west of Lake Bonneville at its highest level. Original vertebrate skeletal material (mostly mammalian) has been found in shallow dry dust 61 m (200 feet) inside the cave. Radiocarbon dates show that fossils have been accumulating since at least 23,000 Y. B. P. It appears that wood rats and possibly small carnivores transported the fossils into the cave because only the smallest elements of large mammals are represented.

The fossil assemblage represents a much more boreal community than the present local fauna. Fish, *Ondatra zibethicus*, and *Mustela cf. vison*, which require perennial water, were recovered, as were *Ochotona princeps*, *Lepus cf. americana*, *Microtus cf. pennsylvanicus*, *Vulpes vulpes*, and *Martes americana*, which have also been extirpated from the Snake Range. *Marmota flaviventris*, *Neotoma cinerea*, cf. *Cercus elaphus*, and *Ovis canadensis* were recovered but now occur only at higher elevations in the range. Extinct taxa recovered are *Smilodon cf. fatalis*, *Equus* species, *Camelops cf. hesternus*, *Hemiauchenia cf. macrocephala*, cf. *Symbos cavifrons*, and a new species of *Brachyprotoma*, herein named *B. brevimala*. This is the first recovery of *Brachyprotoma* from the western United States.

Crystal Ball Cave is 4.8 km (3 miles) northwest of the town of Gandy, Utah, and 0.9 km (0.6 miles) east of the Utah-Nevada border (Sec. 30, T. 15 S, R. 19 W, Salt Lake Base Line and Meridian) in the northeast side of Gandy Mountain, a small outlier on the northeastern edge of the Snake Range (Figs. 1 and 2). The cave is at an elevation of 1760 m (5775 feet), 195 m (644 feet) above Lake Bonneville at its highest level (see Curry 1982, Gilbert 1890) and has about 150 m (500 feet) of passage and a floor area of about 1860 square m (20,000 square feet). Calcite crystals and speleothems cover most of the cave walls and floors, but some shallow sediments are present that contain locally abundant unaltered vertebrate fossils.

It is uncertain if native Americans knew of Crystal Ball Cave, for no ancient human artifacts were found in this study. The cave was discovered by the late George Sims of Gandy in February 1956. He found the original 1-m (3-foot) diameter entrance that leads into a large chamber (Fig. 3). The original east entrance was enlarged, the north entrance was blasted out through a soil-filled passage at the other end of the cave (Fig. 3), and other improvements were made by Cecil R. and Jerald C. Bates of Gandy, Utah, and Thomas E. Sims of Elko, Nevada (J. C. Bates 1983, pers. comm.).

Herbert H. Gerisch and Robert Patterson collected bones from site 1 (Fig. 3) in 1956 that they donated to the Los Angeles County Mu-

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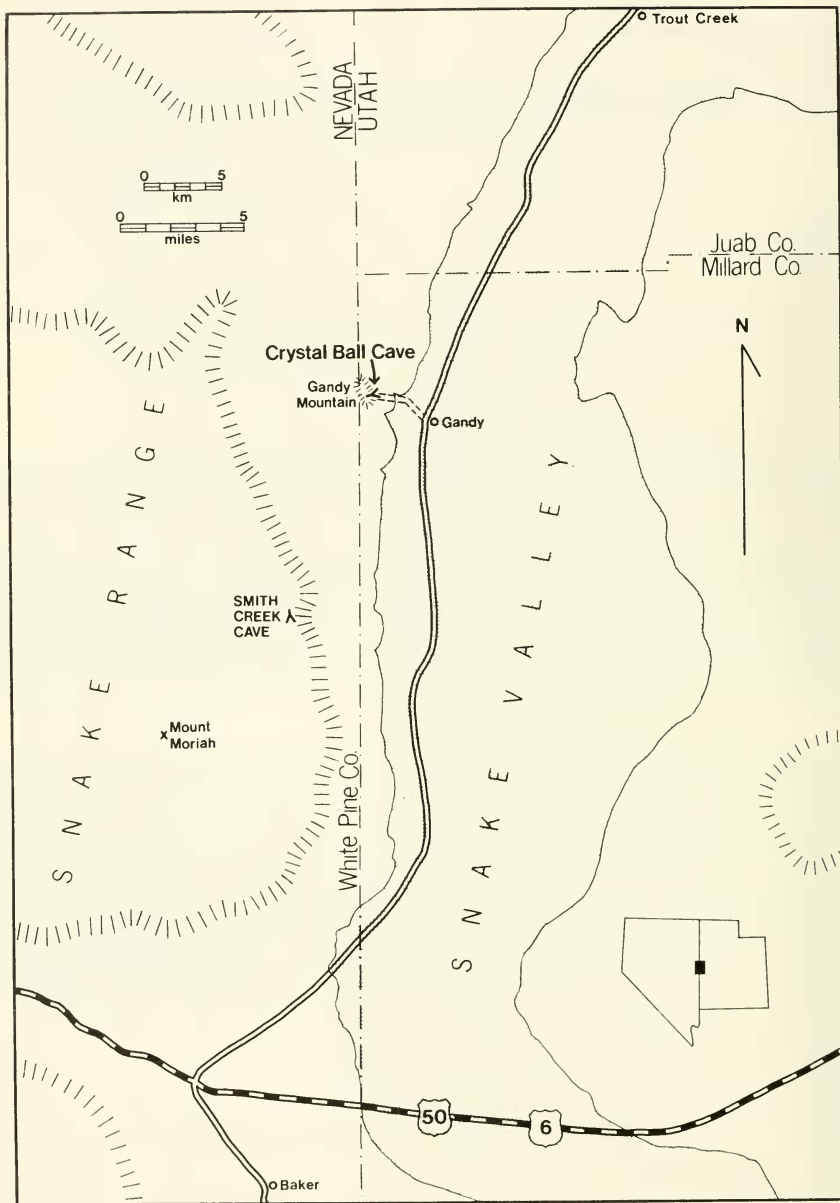


Fig. 1. Index map showing the location of Crystal Ball Cave and other features of the Snake Range and Snake Valley. The stippled area represents the extent of Lake Bonneville at the Bonneville Level.



Fig. 2. Looking west at Gandy Mountain. The arrow marks the location of Crystal Ball Cave.

seum (H. H. Gerisch 1983, pers. comm.). Later Michael Stokes of the Los Angeles County Museum collected additional specimens from site 1. These early collections consisted of float only and included bones of extinct horses and camels. On at least one of these early expeditions, some specimens were also collected from Gandy Mountain Cave, a smaller cave that lies about 0.4 km ($\frac{1}{4}$ mile) south of and 30 m (100 feet) higher than Crystal Ball Cave. Specimens from these two caves are indistinguishable in the Los Angeles County Museum collection because the cave in which each specimen was recovered was not recorded. I dug several test pits in Gandy Mountain Cave in 1981 and found preservation to be poor and specimens to be few and probably all Recent. So, although some specimens were collected from Gandy Mountain Cave, they are not considered in this study, except some which may be among the Los Angeles County Museum collection.

The first extensive collecting in Crystal Ball Cave was done in 1977 by Wade E. Miller and his students from Brigham Young University,

who used fine screens to obtain thousands of specimens (all from site 1). Miller (1982) described this investigation and listed the genera identified in a report on vertebrate fossils from Lake Bonneville deposits. Miller and I operated similar collecting projects in 1981 and 1982 (sites 1, 2, and 3), and I wrote a preliminary report on this study (Heaton 1984). Crystal Ball Cave is Los Angeles County Museum locality 4534 and Brigham Young University vertebrate paleontology locality 772; the specimens from the cave are catalogued as LACM 123655-123711 and BYUVP 5300-8888, 8911-8933. Taxa recovered are listed in Table 1.

The Crystal Ball Cave assemblage is the first Late Wisconsinan age fauna to be described from the state of Utah. Although Utah has extensive Pleistocene deposits from Lake Bonneville, surprisingly few vertebrate fossils have been recovered from them (Miller 1982). The only other Pleistocene assemblage that has been described from Utah is the Silver Creek fauna of north central Utah, 22 km (14 miles) east of and 360 m (1200 feet) above Lake

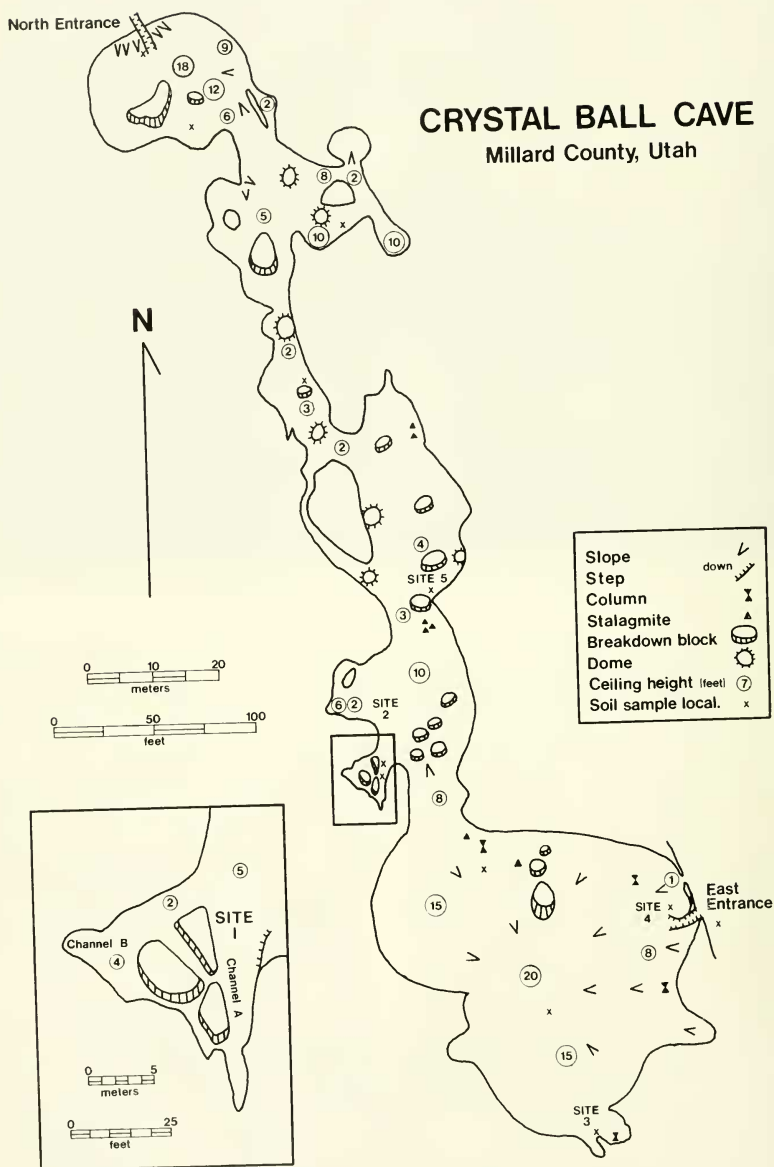


Fig. 3. Planimetric map of Crystal Ball Cave (modified from Halliday 1957) showing the location of fossil sites.

TABLE 1. List of taxa recovered from Crystal Ball Cave.

Taxa recovered	Common name	Minimum number of individuals, including referred material	Current range and status
Kingdom Plantae			
Division Tracheophyta			
Class Gymnospermae			
Subclass Gnetales			
Family Ephedraceae			
<i>Ephedra</i> cf. <i>viridis</i>	Mormon tea	1	* 3
Class Angiospermae			
Subclass Dicotyledoneae			
Family Asteraceae			
<i>Chrysothamnus</i> sp.	rabbitbrush	1	* 3
<i>Haplopappus nanus</i>	goldenweed	1	* 3
<i>Perityle stansburii</i>	rockdaisy	1	* 3
Family Brassicaceae	mustard	1	* 3
Family Cactaceae			
<i>Opuntia</i> sp.	cactus	1	* 3
Family Caprifoliaceae			
<i>Symphoricarpos</i> cf. <i>longiflorus</i>	snowberry	1	* 3
Family Poaceae			
cf. <i>Elymus</i>	wildrye	1	* 3
cf. <i>Panicum</i>	panicgrass	1	* 3
Kingdom Animalia			
Phylum Mollusca			
Class Gastropoda			
Order Pulmonata			
Family Helicidae			
<i>Oreohelix strigosa</i>	land snail	9	* 1
Phylum Arthropoda			
Class Crustacea			
Order Isopoda			
Family ? Armadillidae	pill bug	1	* 3
Class Insecta			
Order Coleoptera			
Family Scarabaeidae			
<i>Aphodius distinctus</i>	dung beetle	1	i 3
Phylum Chordata			
Class Osteichthyes			
Infraclass Teleostei	fish	3	* × 3
Class Reptilia			
Order Squamata	lizards and snakes	67	* × 3
Class Aves	birds	15	* × 3
Class Mammalia			
Order Insectivora			
Family Soricidae			
<i>Sorex</i> sp.	shrew	14	* 3
Order Chiroptera			
Family Vespertilionidae			
<i>Myotis</i> sp.	mouse-eared bat	3	* 2
? <i>Plecotus townsendii</i>	Townsend's big-eared bat	0	* + 3
<i>Antrozous pallidus</i>	pallid bat (large bat)	2	* 2

Key to symbols

* Taxon has been reported living in the Snake Range in Recent times by Durrant (1952) and/or Hall (1981).

i Taxon lives in the Snake Range but was introduced by man in Recent times.

e Taxon has been extirpated from the Snake Range.

† Taxon is extinct.

+ Taxon has been captured live in Crystal Ball Cave by author.

× Taxon has been reported in Snake Valley near Gandy by J. C. Bates (1983, pers. comm., 1984, pers. comm.).

0 Taxon does not presently live in the Snake Range or Snake Valley.

1 Taxon lives in the Snake Range but rarely if ever comes as low as Snake Valley.

2 Taxon lives in the Snake Range and occasionally comes into Snake Valley.

3 Taxon presently lives in Snake Valley around Gandy.

TABLE 1 continued.

Taxa recovered	Common name	Minimum number of individuals, including referred material	Current range and status
Order Lagomorpha			
Family Ochotonidae			
<i>Ochotona princeps</i>	pika	15	e 0
Family Leporidae			
<i>Sylvilagus idahoensis</i>	pigmy rabbit	3	* 3
<i>Sylvilagus nuttallii</i>	Nuttall's cottontail	4	* × 3
<i>Lepus cf. americanus</i>	snowshoe rabbit	1	e 0
<i>Lepus townsendii</i>	white-tailed jackrabbit	10	* 1
<i>Lepus californicus</i>	black-tailed jackrabbit	1	* × 3
Order Rodentia			
Family Sciuridae			
<i>Marmota flaviventris</i>	yellow-bellied marmot	41	* 1
<i>Spermophilus townsendii</i>	Townsend's ground squirrel	288	* × 3
<i>Ammospermophilus cf. leucurus</i>	white-tailed antelope squirrel	2	* 3
<i>Eutamias minimus</i>	least chipmunk	4	* × 3
<i>Eutamias dorsalis</i>	cliff chipmunk	4	* × 3
Family Geomyidae			
<i>Thomomys umbrinus</i>	southern pocket gopher	9	* 3
Family Heteromyidae			
<i>Perognathus cf. formosus</i>	long-tailed pocket mouse	2	* 3
<i>Microdipodops megacephalus</i>	dark kangaroo mouse	7	* 3
<i>Dipodomys microps</i>	chisel-toothed kangaroo rat	5	* 3
Family Cricetidae			
<i>Peromyscus maniculatus</i>	deer mouse	2	* + 3
<i>Peromyscus cf. crinitus</i>	canyon mouse	2	* 3
<i>Peromyscus cf. truei</i>	pinion mouse	1	* 3
<i>Neotoma lepida</i>	desert wood rat	3	* + 3
<i>Neotoma cinerea</i>	bushy-tailed wood rat	57	* 1
<i>Ondatra zibethicus</i>	muskrat	2	e 0
<i>Microtus cf. longicaudus</i>	long-tailed vole	15	* 3
<i>Microtus cf. montanus</i>	montane vole	2	* 2
<i>Microtus cf. pennsylvanicus</i>	meadow vole	1	e 0
<i>Lagurus curtatus</i>	sagebrush vole	28	* 3
Order Carnivora			
Family Canidae			
<i>Canis cf. latrans</i>	coyote	1	* × 3
<i>Canis cf. lupus</i>	gray wolf	1	* 3
<i>Vulpes vulpes</i>	red fox	3	e 0
<i>Vulpes velox</i>	kit fox	2	* × 3
Family Mustelidae			
<i>Mustela cf. frenata</i>	long-tailed weasel	3	* × 3
<i>Mustela cf. vison</i>	mink	1	e 0
<i>Martes americana</i>	marten	2	e 0
<i>Brachyprotoma brevimala</i> , sp. nov.	western short-faced skunk	1	† 0
Family Felidae			
<i>Smilodon cf. fatalis</i>	saber-tooth cat	1	† 0
<i>Felis concolor</i>	mountain lion	1	* × 2
<i>Lynx cf. rufus</i>	bobcat	1	* × 3

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TABLE 1 continued.

Taxa recovered	Common name	Minimum number of individuals, including referred material	Current range and status
Order Perissodactyla			
Family Equidae			
<i>Equus</i> cf. <i>scotti</i>	large horse	2	† 0
<i>Equus</i> ? <i>conversidens</i>	small horse	4	† 0
Order Artiodactyla			
Family Camelidae			
<i>Camelops</i> cf. <i>hesternus</i>	camel	2	† 0
<i>Hemiauchenia</i> cf. <i>macrocephala</i>	llama	1	† 0
Family Cervidae			
cf. <i>Cervus elaphus</i>	wapiti	1	* 1
<i>Odocoileus hemionus</i>	mule deer	11	* × 3
Family Bovidae			
<i>Antilocapra americana</i>	pronghorn	1	* × 3
<i>Ovis canadensis</i>	bighorn sheep	1	* × 2
<i>Ovis</i> cf. <i>aries</i>	domestic sheep	1	i × 3
cf. <i>Symbos cavifrons</i>	musk ox	1	† 0

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Bonneville's highest level and of Late Sangamon to Early Wisconsinan age (Miller 1976).

The nearest described Pleistocene vertebrate localities are four shelters located in Smith Creek Canyon, White Pine County, Nevada, 14 km (9 miles) south of Crystal Ball Cave. New species of mountain goat (Stock 1936), eagle (Howard 1935), and gigantic vulture (Howard 1952) were described from Smith Creek Cave, the primary site. Literature on the Smith Creek Canyon sites includes a description of the avifauna by Howard (1952), the micromammalian fauna by Goodrich (1965), the herpetofauna by Brattstrom (1976), the whole fossil assemblage by Miller (1979) and Mead et al. (1982), and the archaeology by Bryan (1979), Harrington (1934), and others. Although the Crystal Ball Cave fauna is chronologically and geographically close to that of Smith Creek Canyon, it differs in having its fossils deep in the cave, and this has resulted in significant differences between these assemblages. Crystal Ball Cave, for example, has more abundant mammal fossils but less abundant bird fossils than the Smith Creek Canyon sites.

The Crystal Ball Cave assemblage contains only small bones with a maximum length of about 10 cm and maximum weight of about 50 grams. Since only the smallest elements of the large species, which have rarely been considered in other studies, are represented, some problems exist in identifying them. The assemblage, however, is very large and is important because few assemblages of Late Pleistocene age have been reported from the region. The size of this assemblage and the time restraints upon the project have limited the depth to which each taxon could be studied. For taxa with large numbers of specimens, only the best specimens were considered. Additional work could turn up more species, and statistical studies on the more abundant taxa could yield much additional information.

GEOLOGY OF THE CAVE

The Snake Range is a north-south-trending Basin and Range horst composed of Early Paleozoic rocks. Gandy Mountain is an outlier of this range (Gilbert 1890, Nelson 1966). The

cave lies in unnamed Middle Cambrian limestone on the upper plate of the Snake Range Thrust Fault, which is exposed at the north and south ends of Gandy Mountain (Nelson 1966). The massive beds around the cave strike N35W and dip 20NE (Halliday 1957), following the local trend throughout Gandy Mountain (Nelson 1966). The limestone is cavernous and contains many small solution cavities, in addition to Crystal Ball and Gandy Mountain caves.

I have recognized four distinct stages of the cave's history: (1) a period of dissolution of limestone to form the cave; (2) a period of precipitation forming a layer of large calcite crystals ("nail head" spar) up to 0.3 m (1 foot) thick on the cave walls, ceiling, and floor; (3) a period of partial dissolution of these crystals in the upper portions of the cave, the appearance of joints that cut the large calcite crystals, and the dislodging of breakdown from the ceiling of the large entrance room; and (4) the formation of vadose calcite speleothems and influx of sediment and fossils from outside the cave.

The beginning of stage 1, the dissolution of the cave, is of uncertain date. Davis (1930) demonstrated that limestone dissolution to form caves occurs predominantly in a thin zone just below the water table, which is rich in carbon dioxide from groundwater percolating down from the surface. Once it reaches the water table, this groundwater dissolves the rock as it moves very slowly down the water table slope (Davies 1960). This appears to be the case in Crystal Ball Cave, since no scalloped or stream-cut passages are present to suggest the presence of fast-moving water expected in an above-water table origin (Malott 1938, Myers 1969). The cave tends to parallel the strike of the beds and is relatively horizontal, as would be expected if the cave were formed at the water table. Green (1961) cited evidence that some caves in western Utah predate the tilting associated with the Basin and Range uplift. The fact that Crystal Ball Cave is roughly horizontal and parallel to the strike of the beds suggests that it postdates this tilting. But, since the cave is high in a small, isolated hill, considerable uplift and/or erosion must have taken place since the cave was at the water table. The cave does not parallel the present land surface as the water

table tends to do (Myers 1969), and this further suggests that much overburden has been removed since the original dissolution of the cave.

Stage 2, the precipitation of large calcite crystals, represents a different groundwater environment than the preceding dissolutional stage. It is generally agreed that such "nail head" spar forms in still, calcite-saturated water where nucleation centers are free to grow into large euhedral crystals (Hill 1976). This shift from dissolution to precipitation does not necessarily represent a significant change in the level of the water table, but it does represent the drastic reduction in the carbon dioxide content of the groundwater necessary for calcite precipitation (Moore and Nicholas 1964). Several vertical cavities (domes) extend upward into the cave ceiling, and these predate the calcite precipitation because they are partly filled by it. Moore and Nicholas (1964) cited evidence that such domes form late in cave dissolution and provide more direct water and air connections to the surface. Myers (1969) stated that they are of vadose (above water table) origin and caused by vertical seepage. Perhaps the formation of these domes allowed gas exchange between the groundwater in the cave and the surface, permitting carbon dioxide to escape and calcite to be precipitated.

Stage 3 includes several events that are not chronologically separable. Some of the calcite crystals in the roof of the cave are completely dissolved, and locally some of the limestone bedrock underneath it is also. This is especially evident in the aforementioned domes. Joints and breakdown, both of which cut the previously formed calcite crystals, probably represent one or several earthquakes. If any uplift postdates the cave's origin, it probably occurred during this stage. These cracks and breakdown blocks were later filled and covered by the speleothems of stage 4, showing their chronologic relationship.

Stage 4 postdates the loss of voluminous standing water in the cave and the opening of entrances large enough to allow considerable gas exchange and sediment into the cave. Vadose speleothems such as the stalactites, columns, and rimstone pools found in Crystal Ball Cave form subaerially in caves having enough gas exchange with the surface to allow

carbon dioxide to escape from the dripping groundwater (Moore and Nicholas 1964). Near the east entrance of the cave some small columns have formed upon and been partly covered by sediment coming in from the entrance, showing the concurrence of these events. The vertebrate material under study entered the cave during stage 4, when cave openings were sufficiently large to allow their entry and dry conditions allowed their preservation; therefore cave stages 1 through 3 pre-date the oldest fossils.

Twelve sediment samples were collected at sites throughout the cave and screened to determine the degree of sorting. All samples are poorly sorted, but samples farthest from known entrances tend to have a higher percentage of fine particles. Particles under 0.061 mm (0.0024 inch) in diameter make up over half the weight percent of three such samples. Samples were placed in hydrochloric acid to remove all calcite. Sediment from site 1 (Fig. 3) is composed of about 80% calcite and 20% very fine but poorly sorted clastic grains, namely quartz, mica, and an unidentified ferromagnesian mineral. Larger clastic grains were found in samples closer to each entrance and comprised greater portions of the sediment.

The calcite portion of the sediment is composed of both crystal fragments, probably derived from broken "nail-head" spar, and cryptocrystalline caliche-like crust associated with clastic fragments, almost certainly precipitated in the cave. The clastic fragments could have been washed in, blown in, brought in by animals, released from the cave walls as impurities in the limestone, or a combination of these factors. The sediments at site 1 show no sign of ever having been wet except in some areas where they have been cemented with calcite. But water does run in through the east entrance during storms, filling the large entrance chamber with mud. Wind gusts can be quite strong through the cave during storms, but only because the north entrance was artificially opened. The importance of these factors is difficult to determine, but the fact that the bulk of the sediment far inside the cave is calcite suggests that the sediments are mostly derived from within the cave by weathering of the limestone and calcite crystals rather than from outside sources.

METHODS

The dry, dusty sediments of sites 1 and 2 are composed of nearly 10% vertebrate bones by volume. These fossiliferous sediments are unstratified and never more than 0.5 m (1.5 feet) thick, so no meaningful relative dating is feasible. Collecting was done mainly at sites 1 and 2, but a few specimens were taken from sites 3 and 4 (Fig. 3). No significant differences were found between fossils from the various sites, so the site at which each specimen was collected is not reported here but can be found in the Brigham Young University Vertebrate Paleontology Laboratory catalogs.

On early collecting trips most of the field time was spent digging through the sediments and collecting specimens by hand. Sediment was also taken to the lab in bags and screened to recover smaller bones and teeth. After using this method for several trips, the collection had overwhelming numbers of rodent and lagomorph fossils, but bones of larger mammals were few. So, on the last collecting trip, large volumes of cave sediment were screened inside the cave with a coarse screen, and the number of larger bones in the collection was thereby more than doubled.

Little laboratory preparation was necessary with the larger Crystal Ball Cave fossils. A few required removal of hardened dirt or calcite. All were washed to remove dust. Considerable time was spent manually separating small bones and teeth from cave sediments. This was done in the laboratory with forceps after the sediments had been washed through a fine screen and allowed to dry. Approximately 1 cubic meter (35 cubic feet) of cave sediment was prepared in this manner, and virtually all the bone was removed.

Because of the great abundance of small mammal fossils recovered, only the skulls and jaws were studied. All identifiable material was used for larger mammals because they were not as well represented and because few dental elements were recovered. Identification was made by comparison to Recent specimens housed at the Brigham Young University Monte L. Bean Museum, fossil and Recent specimens housed at the Brigham Young University Vertebrate Paleontology Laboratory, and by extensive use of the literature.

TABLE 2. Radiometric dates of bone samples from Crystal Ball Cave provided by Geochron Laboratories, Cambridge, Massachusetts in July 1984.

Cat. Number	Taxon	Description	Age
Uncataloged	large mammal	Limb bone fragment	12,950 + 2650 – 2000 years B.P.
Uncataloged	large mammal	Middle limb bone	15,600 + 2000 – 1600 years B.P.
BYUVP 7687	<i>Equus</i> (small)	Thoracic vertebra	15,820 + 1510 – 1270 years B.P.
BYUVP 7568	<i>Equus</i> (small)	Distal metapodial	More than 23,000 years B.P.

Small living mammals were captured inside Crystal Ball Cave and around Gandy Spring at the base of Gandy Mountain. This trapping was not extensive, but it did indicate what species are abundant in and around the cave. The species trapped are recorded in Table 1. Jerald C. and Marlene Bates of Gandy (1983, pers. comm., 1984, pers. comm.) were interviewed for additional information about the modern local fauna and recent history of the cave, including its modification by man.

ANTIQUITY OF THE ASSEMBLAGE

One problem with the Crystal Ball Cave assemblage is that it is impossible to separate fossil bones from Recent bones using superposition, because the sediments in which they are found are shallow and unstratified. Some of the best specimens of extinct species were found on the surface by early expeditions. The cave seems to have been accumulating fossils continuously from some date in the past, when an entrance was formed, until the present. The purpose of radiometric dating was to establish when fossils were first deposited and if the rate of fossil deposition has been uniform since then.

Four bone samples were sent to Geochron Laboratories, Cambridge, Massachusetts, for carbon-14 dating. Because of the small size of bones in the assemblage, these samples (which included some of the largest recovered) were just over 25 grams, the minimum weight suggested for dating. Two were of small extinct horses: a thoracic vertebra (BYUVP 7687) and a distal metapodial epiphysis (BYUVP 7568); and two were fragments of unidentified limb bones of large mammals. Geochron Laboratories cleaned and washed the four samples in acetic acid to remove adhering materials, then crushed them and soaked them in agitated acetic acid for 24 hours to remove normal carbonates. The samples were then hydrolized under vacuum with

hydrochloric acid to dissolve bone apatite and evolve its carbon dioxide for collection. The carbon dioxide samples were converted to methane and counted in a low-background beta counter (with C-13 correction), and dates were based on the Libby half-life (5570 years). The ages reported are listed in Table 2. The oldest date of "over 23,000 Y.B.P." was given because no C-14 was detected in that sample.

The oldest date of 23,000+ Y.B.P. gives a minimum age for the time fossils first entered the cave. The youngest horse bone date of about 19,000 Y.B.P. gives a maximum age for the loss of that species from the area, although other studies have shown that small horses lived beyond 10,370 Y.B.P. in Idaho and until about 8,000 Y.B.P. in Arizona and Alberta, Canada (Kurten and Anderson 1972, 1980, Martin 1967). Otherwise the four dates give only a general age for the assemblage and provide no information about the antiquity of individual taxa. The fact that all four dates are over 12,000 Y.B.P. suggests that bones, at least of large mammals, may have been deposited more frequently during the Late Pleistocene than during the Recent. If so, this could be due to a greater abundance of the animals themselves, a change in what animals (or other processes) deposited the fossils, or the former presence of larger or additional entrances.

Thirty radiometric dates have been reported from the Smith Creek Canyon sites (Thompson 1979, Thompson and Mead 1982, Valastro et al. 1977), and they demonstrate that accumulation of fossils there was concurrent with fossil deposition at Crystal Ball Cave. The two oldest Smith Creek dates are 28,650 Y.B.P. (Smith Creek Cave) and 27,280 Y.B.P. (Ladder Cave), which correlate well with the date of "over 23,000 Y.B.P." from Crystal Ball Cave. The other 28 Smith Creek Canyon dates are younger than 18,000 Y.B.P., with the majority being from 10,000

to 13,000 Y.B.P. The mean age of the four dated Crystal Ball Cave specimens is considerably older than the mean age of dated specimens from any of the Smith Creek Canyon sites, suggesting that its major period of fossil deposition was earlier; but a sample size of four dates is not statistically significant enough to demonstrate this.

PALEOECOLOGICAL SETTING

The Pleistocene-Recent boundary was a period of intense climatic and faunal change in North America. The changes at this fossil site were particularly drastic due to its close proximity to Lake Bonneville, which dried up during the period that fossils were being deposited. According to Currey (1982), the Bonneville Level terraces at Gandy are at an elevation of 1565 m (5165 feet), showing that the lake rose to 195 m (644 feet) below and 1.7 km (1 mile) east of Crystal Ball Cave and filled Snake Valley as far as 60 km (36 miles) south of the cave (Fig. 1). My previous statement that Gandy Mountain was once an island in Lake Bonneville (Heaton 1984) was based on data from an earlier study and is unconfirmed. Lake Bonneville started its last cycle of filling prior to 26,000 Y.B.P. and reached its highest level (Bonneville Level) about 16,000 Y.B.P. (Currey 1982, Scott et al. 1983). The lake remained at the Bonneville Level until 14,000 or 15,000 Y.B.P. when the flood at Red Rock Pass, Idaho, dropped the lake to the Provo level, where it remained until about 13,000 Y.B.P. (Currey 1982, Scott et al. 1983). At the Provo level the lake had only a shallow arm extending southward into Snake Valley to a point 8 km (5 miles) east of Crystal Ball Cave (Currey 1982). Further lowering of the lake after 13,000 Y.B.P. caused its quick retreat northward out of Snake Valley to a point 65 km (40 miles) northeast of the cave by 10,300 Y.B.P. (Currey 1982). Based on these dates Lake Bonneville was very close to Crystal Ball Cave for at least half the time that fossils were being deposited and within Snake Valley for about two-thirds of that time or longer. Then, within a few thousand years, the fossil site changed from being near the shore of a large continental lake to being in a dry desert, as it is today.

In addition to Lake Bonneville, many pluvial lakes filled the valleys of Nevada, includ-

ing one just west of the Snake Range, 30 km (18 miles) west of Crystal Ball Cave (Mifflin and Wheat 1979). Based on studies of temperature and precipitation correlation, Mifflin and Wheat (1979) estimated that development of pluvial lakes in the area involved a temperature decrease of 3 C (5 F). Lower temperatures and higher annual precipitation caused floral boundaries to move lower in elevation and latitude during the Wisconsin glacial (Thompson and Mead 1982, Wells 1983). This shift had a dramatic effect on small boreal mammals in the Great Basin because it allowed them to disperse between ranges, whereas now the intermontane basins act as absolute barriers (Brown 1971, 1978, Harper et al. 1978). Brown (1971, 1978) demonstrated that distribution of small boreal mammals is relictual from the Wisconsin glacial and not a case of colonization-extinction equilibrium. The Crystal Ball Cave fauna shows what taxa have been extirpated from the Snake Range since the Wisconsin glacial, and it documents northward shifts in the ranges of several species at the close of the Pleistocene.

Another striking feature of the Late Pleistocene is the well-documented megafaunal extinction. At the end of the Wisconsin glacial, 41 species of large mammals went extinct—3 times more than at the end of any of the other Pleistocene glacials (Kurten and Anderson 1980). Different workers have attributed this to a rapid postglacial climatic shift (Martin and Neuner 1978, Webb 1969) and to overkill by early man (Martin 1967, Mosimann and Martin 1975). The Crystal Ball Cave assemblage contains several of these extinct taxa, but the fact that it lacks human association and stratigraphic control makes it unable to provide any substantial data to resolve this controversy.

Consideration needs to be given to the role Crystal Ball Cave played as a shelter and the means by which fossils got into the cave. When the cave was discovered in 1956, the east entrance was a 1-m (3-foot) diameter opening in solid rock, half filled with soft soil, which sloped downward into the large entrance chamber (Fig. 3). Several 0.3-m (1-foot) diameter entrances (which are often filled with woodrat nesting material) also exist just north of the east entrance. The north entrance was completely filled with debris,

which if removed could make it 2.5 m (8 feet) high and 6 m (20 feet) wide. It could have been a large important entrance when the earlier bones were being deposited, but several factors preclude this. First, there are very few fossils in the deep dry sediments of the north half of the cave; the rich bone deposits are in the south half. Second, the fossil assemblage provides no evidence that there ever was a large entrance since large mammals are represented only by their smallest elements. If the north entrance ever was large, it was probably prior to deposition of the fossils under study.

Neotoma lepida, *Peromyscus maniculatus*, and *Plecotus townsendii* were captured alive inside the cave, so their presence in the assemblage is easy to explain. Other small mammals could also have lived in the cave or used it as a shelter. Small carnivores and scavengers could have brought their prey into the cave to eat. The presence of only the smallest isolated elements of large mammals suggests that these bones were brought into the cave individually after the carcasses deteriorated. Small carnivores could have contributed to this, but it is my opinion that these bones were taken into the cave primarily by wood rats since these animals are known to take materials into the cave now, many bones have rodent gnaw marks, and all the bones in the assemblage are small enough for a wood rat to transport. Because the cave has small entrances and because the bones are found far within the cave, it is very unlikely that birds transported prey inside. There is also no evidence that prehistoric humans brought material into Crystal Ball Cave. This suggests that the species found in the assemblage lived and died in or near the cave and were not transported long distances, as could have occurred at Smith Creek Cave (Bryan 1979, Harrington 1934).

It is unusual for caves to have their richest bone deposits far inside the cave rather than near an entrance. The east entrance of Crystal Ball Cave takes in water during storms, and other areas are damp from seepage. Sites 1 and 2, which contain the richest bone deposits, are in one of the driest areas of the cave and are just outside the zone of total darkness when the sun shines through the east entrance. North of sites 1 and 2 the passage constricts and enters total darkness but

remains dry. Wood rat nests are particularly common at sites 1 and 2, which helps explain why rich bone deposits are present if wood rats play an important role in getting them there. The extremely dry conditions at sites 1 and 2 and their proximity to the east entrance, which I consider the primary entrance, are probably the reason why these sites have been so productive. Rarity of fossils nearer the east entrance is probably due to poorer preservational conditions and poorer sites for wood rat dwellings. Lack of rich bone deposits in the northern half of the cave is probably due to constricted passages and greater distance from a Late Pleistocene entrance.

The following taxa were recovered from Crystal Ball Cave.

KINGDOM PLANTAE
Division Tracheophyta
Class Gymnospermae
Family Ephedraceae
Ephedra cf. *viridis*

MATERIAL.—Two stem fragments.

Class Angiospermae
Family Asteraceae
Chrysothamnus sp.

MATERIAL.—One branching stem fragment.

Haplopappus nanus

MATERIAL.—One group of involucre, 4 single involucre.

Perityle stansburii

MATERIAL.—Four involucre on stem fragments.

Family Brassicaceae
Genus and species indet.

MATERIAL.—Two stem fragments, 2 stem fragments with empty seed capsules, 4 empty seed capsules.

Family Cactaceae
Opuntia sp.

MATERIAL.—Twelve spines.

Family Caprifoliaceae
Symphoricarpos cf. *longiflorus*

MATERIAL.—One branching stem fragment, 4 straight stem fragments, 56 leaves and partial leaves.

Family Poaceae
cf. *Elymus*

MATERIAL.—Two fruits.

cf. *Panicum*

MATERIAL.—Three connected fruits, 3 rachis fragments.

DISCUSSION.—About 250 small plant fragments were recovered from the Crystal Ball Cave sediments by the same process that small bones and teeth were recovered. From among them Howard C. Stutz (1984, pers. comm.), a botanist at Brigham Young University, identified the above taxa. All the taxa identified still live in the immediate area of Crystal Ball Cave (partly because a sample of plants from immediately around the cave comprised most of the comparative material), so they do not document any floral changes since the Pleistocene. Further research could turn up additional taxa since not all the plant fragments were identified.

The great abundance of *Symphoricarpos* compared to the other plant taxa recovered is noteworthy. Stutz (1984, pers. comm.) found a thicket of *Symphoricarpos* at the bottom of a cliff in the nearby House Range that was full of rodent nests and burrows. This suggests that this plant is a favorite nest-building material for rodents, and wood rats may have brought pieces of it into Crystal Ball Cave for that purpose.

No pollen analysis has been done at Crystal Ball Cave, and no pollen was noticed in the cave sediments studied. A more extensive search could turn up pollen, however, and, since plant fragments are rare in the sediments, it could help identify what plants inhabited the area during the Pleistocene.

KINGDOM ANIMALIA
Phylum Mollusca
Class Gastropoda
Order Pulmonata
Family Helicidae
Oreohelix strigosa

MATERIAL.—Nine complete shells ranging from 3 to 10 mm in diameter.

DISCUSSION.—These land snails, which still inhabit the Snake Range, live in moister conditions than those at Crystal Ball Cave today (Chamberland and Jones 1929), so they are probably late Pleistocene or early Recent in age. Since there are only nine specimens, they were probably never abundant near the cave, but lack of abrasion on the shells suggests that they were not transported far.

Phylum Arthropoda
Class Crustacea
Order Isopoda
Family ? Armadillidae
Genus and species indet.

MATERIAL.—Partial dried shell.

DISCUSSION.—Pill bugs are native to North America (S. L. Wood 1984, pers. comm.), and little work has been done on them. Representatives of several families, including family Armadillidae, presently live in Utah, but the partial specimen did not allow further identification. These terrestrial crustaceans inhabit moist recesses throughout Utah and Nevada today, so the presence of this specimen is not surprising, although little can be said about its age.

Class Insecta
Order Coleoptera
Family Scarabaeidae
Aphodius distinctus

MATERIAL.—Complete dried specimen.

DISCUSSION.—This small beetle lives in cattle dung and was introduced from Europe in Recent times (S. L. Wood 1984, pers. comm.). It is therefore Recent in age and has little significance to the assemblage.

Phylum Chordata
Class Osteichthyes
Infraclass Teleostei

MATERIAL.—Thirty-seven amphicoelous vertebrae ranging from 1 to 5 mm in diameter and length (BYUVP 7939–7973).

DISCUSSION.—Presently, the closest water body to Crystal Ball Cave is Gandy Spring on the south side of Gandy Mountain. This

spring emits voluminous warm water (27 C, 81 F) that is high in calcium (J. C. Bates 1983, pers. comm.). Small minnows are the only native fish found living in the stream that exits Gandy Spring, but bass and blue gill were introduced in the 1960s and still survive; carp are also found in reservoirs in the area (J. C. Bates 1984, pers. comm.). Mead et al. (1982) reported *Salmo* and *Gila* from nearby Smith Creek Cave, which is higher in elevation and farther from a perennial water source than Crystal Ball Cave, and Smith (1978) and Smith et al. (1968) reported Pleistocene fish from Lake Bonneville deposits.

A dichotomy in the size of the fish vertebrae from Crystal Ball Cave suggests that at least two species are represented, but no attempt at generic identification has been made. The possibility that these vertebrae are Recent cannot be eliminated, but they probably represent fish that lived in Lake Bonneville when it was at or near the Bonneville level, or in perennial Pleistocene streams in the area. In any case, they had to be transported up Gandy Mountain to the cave site. Carnivores or scavengers could have done this, and wood rats could have taken them inside the cave.

Class Reptilia
Order Squamata

MATERIAL.—Two hundred sixty-five lizard and snake jaws (BYUVP 8004–8217). Postcranial material is also represented but has not been separated from that of mammals.

DISCUSSION.—The reptile specimens have not yet been studied but will be reported in a future paper by Jim I. Mead and Timothy H. Heaton. The reptiles recovered from the deeper levels of Smith Creek Cave demonstrate that their present distribution in the Great Basin is more ancient than previously believed (Brattstrom 1976, Mead et al. 1982). The large number of reptile jaws from Crystal Ball Cave will help establish what species have been extirpated from the area, but, unless dated individually, they will not help establish the antiquity of their ranges.

Class Aves

MATERIAL.—Six hundred eleven specimens representing all skeletal elements of

small passerines and skull and vertebrae fragments of larger forms (BYUVP 6606, 8301–8888, 8911–8933, LACM 123655).

DISCUSSION.—The bird specimens have not yet been studied but will be reported in a future paper by Steven D. Emslie and Timothy H. Heaton. Miller (1982) reported ? *Aquila* from Crystal Ball Cave from among this same material.

Class Mammalia
Order Insectivora
Family Soricidae
Sorex sp.

MATERIAL.—One maxilla pair with all teeth (BYUVP 5321). Another 5 partial maxillae and 27 partial dentaries (some with teeth, BYUVP 5300–5320, 5322–5332) were recovered that cannot be generically identified but compare favorably with *Sorex*.

DISCUSSION.—Identification was based on the presence of five unicuspid teeth behind the upper incisor, the first four of which taper slightly in size posteriorly and are visible laterally, and the last of which is tiny, peglike, unpigmented, and not visible labially. *Microsorex* and *Blarina* also have five unicuspid teeth in each maxilla, but *Microsorex* has only the first three visible laterally and *Blarina* has the third and fourth of subequal and smaller size than in *Sorex*. *Notiosorex* and *Criptotis*, the other two North American genera, have only three and four unicuspid teeth in each maxilla, respectively (Hall 1981). All the other soricid specimens are either lower jaws and teeth, which I was unable to distinguish at the generic level, or are maxillae without the diagnostic unicuspid teeth. All these soricid specimens compare well with *S. vagrans* and *S. palustris*, which presently live in the region of the cave (Hall 1981), but no dental character could be found to distinguish them.

Order Chiroptera
Family Vespertilionidae
Myotis sp.

MATERIAL.—Two palates without teeth (BYUVP 5340, 5357), anterior portion of right maxilla with P4/, M1/ (BYUVP 5338). Twelve right dentaries (BYUVP 5336, 5341–5346, 5352, 5353, 5358–5360) and 12 left dentaries

(BYUVP 5339, 5347–5349, 5354–5356, 5361–5364, 5366) were recovered that are *Myotis* or *Plecotus*.

DISCUSSION.—*Myotis* maxillae have the diagnostic presence of two small unicusps pre-molars following the incisor, as opposed to one or none in all other vespertilionids. Dentaries of *Myotis* and *Plecotus* are virtually identical, both having the dental formula of 1/3, C/1, P/3, P/3 and similar size and proportions, and no character could be found to separate them. Dentaries of *Lasionycteris* and *Pizonyx* also share this tooth formula but are considerably larger. *Myotis* has not been reported living in Crystal Ball Cave, but *M. lucifugus*, *M. evotis*, *M. thysanodes*, *M. volans*, and *M. subulatus* are all found in the region (Hall 1981). Little work has been done to separate species of *Myotis* dentally, and I was unable to find any species variation that was greater than individual variation.

? *Plecotus townsendii*

MATERIAL.—Twenty-four dentaries were recovered of *Myotis* and/or *Plecotus* (as listed and discussed above).

DISCUSSION.—*Plecotus townsendii* is the only bat reported living in the cave. Specimens were captured by Halliday (1957) and by myself in 1982 and 1983. Halliday (1957) and other workers have referred to this bat as *Corynorhinus rafinesquii*, but Handley (1959), in his synthesis of the big-eared bats, considered both *Corynorhinus* and *Idionycteris* as only subgenera of the European genus *Plecotus*. He also regarded *P. rafinesquii* (presently in southeastern U.S.) and *P. townsendii* (presently in western U.S.) as two distinct species. *Plecotus mexicanus*, the third living species of the subgenus *Corynorhinus*, and *P. hyllotis*, the only member of the subgenus *Idionycteris*, both inhabit Mexico and north into the southern tip of Arizona. Two extinct Pleistocene species of the subgenus *Corynorhinus* are also recognized: *P. alleghaniensis* from Cumberland Cave in Maryland and *P. tetralophodon* from San Josecito Cave in Mexico (Handley 1959). Handley (1959) listed no characters to distinguish the dentaries of different species of *Plecotus*, but the bats living in the cave are clearly *P. townsendii*.

Lack of positive evidence for this species in the Crystal Ball Cave assemblage could represent lack of chance preservation or a recent change in the species that inhabit the cave. Since the assemblage contains indistinguishable Pleistocene and Recent specimens, even if the lower jaws could be identified as *Plecotus*, unless dated individually they would not reveal how long this species has inhabited the cave. Humphrey and Kunz (1976) postulated that mild winters during the Late Pleistocene allowed *P. townsendii* to roost in trees rather than caves and to avoid the present habit of long winter hibernation, whereas this bat now uses caves as refugia to survive the intolerably cold post-Pleistocene winters. Humphrey and Kunz (1976) cited evidence that this bat is very sedentary and now survives only in isolated areas where suitable winter hibernacles are available. Handley (1959) stated that very few specimens of *Plecotus townsendii* have been reported considering its large geographic range. Durrant et al. (1955) said this species was thought to only inhabit the southern half of Utah until a few isolated citations were made in northern Utah caves, one of which (in Logan Canyon) contained the bat in large numbers. It is, therefore, very possible that *P. townsendii* has not inhabited Crystal Ball Cave, at least to the large degree that it does now, until Recent times.

Antrozous pallidus

MATERIAL.—Anterior portion of left maxilla with C1/1, P4/ (BYUVP 5365), anterior portion of fused dentary pair with left P/4, M/1 (BYUVP 5351), posterior portion of right dentary with M/2 (BYUVP 5333), posterior portion of left dentary with M/1 (BYUVP 5334). A posterior fragment of a left dentary (BYUVP 5350) and a right M/2 (BYUVP 5335) probably also belong to this taxon based on their large size and chiropteran affinities.

DISCUSSION.—This is the largest species of bat found in the assemblage and is easily distinguishable from other vespertilionids by its unique tooth formula of 11/2, C1/1, P1/2, M3/3, the configuration of the incisors and fenestra in the anterior palate, and the high coronoid process on the dentary. *Antrozous pallidus* has not been reported living in the cave, but it presently occurs from the region

of the cave southward into Mexico and along the west coast of the United States and southern British Columbia. *Antrozous bunker* is now considered a subspecies of *A. pallidus* (Hall 1981). *Antrozous dubiaquercus* occurs in Mexico and Central America and is distinguished from *A. pallidus* by normally having 3 lower incisors instead of 2. *Antrozous koopmani* occurs only in Cuba. All the material listed above matches perfectly with modern *A. pallidus*, which lives in the region of Crystal Ball Cave.

Order Lagomorpha
Family Ochotonidae
Ochotona princeps

MATERIAL.—Anterior portion of skull with all teeth (BYUP 5387), right maxilla with M1/2 (BYUP 5407), right maxilla with M2 (BYUP 5406), right maxilla without teeth (BYU 5385), anterior portion of right maxilla with M1 (BYUP 5404), 2 anterior portions of right maxillae without teeth (BYUP 5386, 5405), 4 partial right maxillae without teeth (BYUP 5368, 5409, 5410, 5412), 6 left maxillae without teeth (BYUP 5381, 5383, 5384, 5396, 5397, 5417), 3 anterior portions of left maxillae without teeth (BYUP 5374–5376), 5 partial left maxillae without teeth (BYUP 5369, 5382, 5408, 5415, 5416), right dentary with P/4, M2/3 (BYUP 5399), right dentary with M2/3 (BYUP 5393), right dentary with M/2 (BYUP 5395), 5 right dentaries without teeth (BYUP 5390–5392, 5401, 5419), partial right dentary with P/4 (BYUP 5370), 4 partial right dentaries without teeth (BYUP 5367, 5411, 5413, 5414), 2 anterior portions of right dentaries without teeth (BYUP 5371, 5372), left dentary with P/4, M1/2 (BYUP 5402), left dentary with M1/2 (BYUP 5398), 3 left dentaries without teeth (BYUP 5394, 5403, 5418), anterior portion of left dentary with P/4, M1/2, 3 (BYUP 5388), posterior portion of left dentary with M1/2, 3 (BYUP 5389), 2 posterior portions of left dentaries without teeth (BYUP 5377, 5400), partial left dentary with M1/2 (BYUP 5378), 3 partial left dentaries without teeth (BYUP 5373, 5379, 5380).

DISCUSSION.—Ochotonids are easily distinguished from leporids by the lingual curve in the maxilla behind the cheek teeth, the

presence of 5 upper cheek teeth rather than 6, and M/3 and its socket being anteroposteriorly short instead of triangular. *Ochotona princeps* presently inhabits high elevations within 190 km (120 miles) of Crystal Ball Cave, both to the east and west (Hall 1981). The only other extant species, *O. collaris*, occurs exclusively in northwestern Canada and Alaska (Hall 1981) and has been found in fossil deposits only in that region (Kurten and Anderson 1980). The only extinct Quaternary North American species of *Ochotona* is *O. whartoni*, which is known from the Early Pleistocene and is distinctly larger than the extant species (Kurten and Anderson 1980). All the specimens listed above are indistinguishable from Recent *O. princeps*.

Why *O. princeps* has been extirpated from the Snake Range is uncertain, but fossils have been recovered from Smith Creek Cave (Miller 1979) and many other Great Basin localities where this species does not live today. For example, Grayson (1977) recovered *O. princeps* dated at 7,000 to 12,000 Y.B.P. from the Fort Rock Basin of south central Oregon. That area is now dominated by sagebrush, grasses, and sparse junipers, but modern pikas in the region only live where there is more succulent vegetation. Grayson (1977) attributed the disappearance of *Ochotona* to either a shift to more xeric habitat or to an eruption of Mt. Mazama 7,000 Y.B.P. A similar extirpation in the Snake Range 500 km (315 miles) to the southeast supports the former of Grayson's hypotheses.

Family Leporidae
Sylvilagus idahoensis

MATERIAL.—Right dentary with P/4, M1/2 (BYUP 5534), right dentary without teeth (BYUP 5444), right dentary fragment with P/3 (BYUP 5584), left dentary with P/3, 4, M1 (BYUP 5536), left dentary fragment without teeth (BYUP 5434).

DISCUSSION.—*Sylvilagus idahoensis* is distinguished from all other leporids by its small size (Fig. 4) and from *Ochotona* by the characters listed above. The P/3 of *S. idahoensis* does not widen posteriorly, as in other species of *Sylvilagus*, and the second reentrant angle is not crenulated as it is in many leporids. BYUP 5536 is larger than any of the 31 Re-

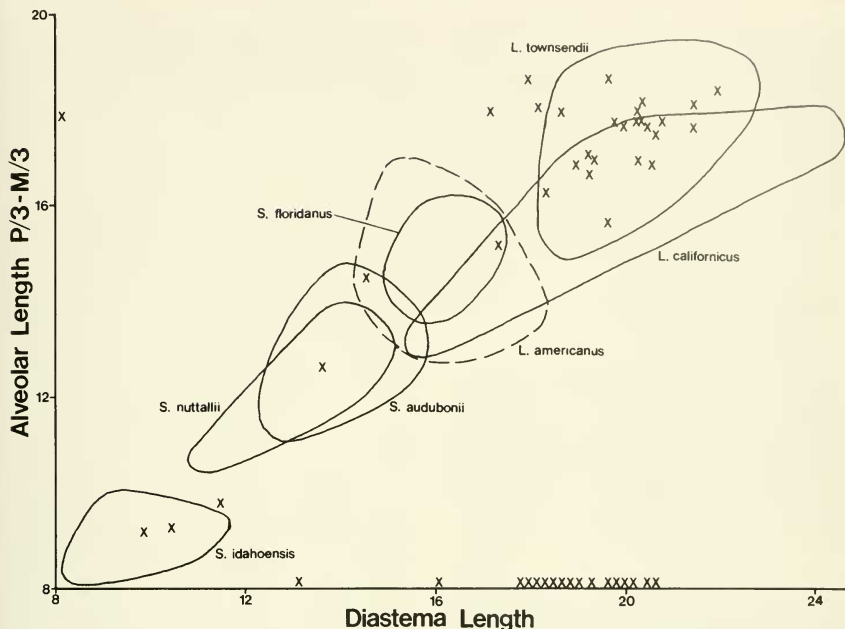


Fig. 4. Plot of *Sylvilagus* and *Lepus* dentaries from Crystal Ball Cave (X's) and ranges of variation for all species of leporids presently living in and near Utah and Nevada (circumscribed). Some of the measurements of Recent specimens were made by the author from the Brigham Young University Monte L. Bean Museum mammal collection, and some were provided by J. A. White (1984, pers. comm.). The number of Recent specimens measured were 31 of *S. idahoensis*, 22 of *S. nuttallii*, 33 of *S. audubonii*, 12 of *S. floridanus*, 40 of *L. americanus*, 36 of *L. californicus*, and 29 of *L. townsendii*. Symbols on the plot margins represent Crystal Ball Cave specimens on which only one of the two plotted measurements could be made. Measurements are in millimeters.

cent *S. idahoensis* specimens to which it was compared (but smaller and distinct from other species of leporids), and the other Crystal Ball Cave specimens are also comparatively large, suggesting that this species may have decreased in size at the end of the Pleistocene. This species presently lives in the region of the cave and to the north and west (Hall 1951, 1981).

Sylvilagus nuttallii

MATERIAL.—Anterior portion of right dentary without teeth (BYUVP 5493), left dentary with M/1 (LACM 123658), anterior portion of left dentary with I/1, P/3, 4, M/1 (BYUVP 5578), 4 right P/3's (BYUVP 5717, 5731, 5769, 5794), 4 left P/3's (BYUVP 5773, 5782, 5795, 5810).

DISCUSSION.—*Sylvilagus* is commonly distinguished from *Lepus* by its smaller size, al-

though there is some overlap (namely, *S. aquaticus* and *S. cunicularius* are larger than *Lepus americanus*; J. A. White 1984, pers. comm.). The species of these genera presently living in the region are usually discernible by size, but the species within each genus are usually not (Fig. 4).

Of the two species of *Sylvilagus* presently living in the Snake Range, *S. audubonii* has a larger mean size and tends to have much more crenulation in the second reentrant angle of P/3 than *S. nuttallii* (although there is overlap in both characters). *Sylvilagus floridanus*, which occurs just south of Utah and Nevada, has an even larger mean size than *S. audubonii* but has little crenulation in the P/3 like *S. nuttallii*. BYUVP 5493 and LACM 123658 compare well in size with *S. nuttallii* and *S. audubonii* (Fig. 4), but none of the nine P/3's of *Sylvilagus* size from Crystal Ball Cave

have much crenulation in the second reentrant angle of P/3, suggesting that they belong to *S. nuttallii* rather than *S. audubonii*. Although other species could be represented, the evidence suggests that at least the majority of the specimens listed above are of *S. nuttallii*.

Sylvilagus nuttallii presently inhabits the region of the cave and northward, whereas *S. audubonii* inhabits the region of the cave and southward. *Sylvilagus nuttallii* also tends to occur at higher elevations and in more wooded or bushy areas than *S. audubonii*, which lives in plains or open country (Hall 1951). Since Candy Mountain is presently covered with only sparse bushes and is surrounded by open plains, the presence of *S. nuttallii* and absence of *S. audubonii* in the assemblage suggests a replacement of woodland-alpine vegetation by the present desert conditions since the Pleistocene.

Lepus cf. americanus

MATERIAL.—Right dentary with /I, P/3./4, M/1./2 (BYUPV 5519), anterior portion of left dentary with P/4, M/1 (BYUPV 5543). A left dentary with /I (BYUPV 5430) falls within the size range of *L. americanus* and *L. californicus*.

DISCUSSION.—The jaw dimensions and P/3 widths of these specimens are intermediate in size between the *Sylvilagus* specimens (described above) and the majority of the *Lepus* specimens (described below). They fall in and near the range of variation of the smallest *L. californicus* and largest *S. audubonii* specimens (Fig. 4), but most of the P/3's of these two species have a highly crenulated second reentrant angle, whereas the P/3 of BYUPV 5519 does not. These specimens are also indistinguishable from *S. floridanus*, but this species has never been reported living or as a fossil from Utah or Nevada.

Lepus americanus does not presently occur in the Snake Range but does occur 160 km (100 miles) to the north and east, mainly at high elevations (Durrant 1952, Hall 1951). Since the assemblage generally contains more species that presently range north of the cave than south of the cave, it is not at all unreasonable that *L. americanus* could have inhabited the region of the cave in the recent geologic

past. Kurten and Anderson (1980) listed a number of Pleistocene fossil sites where *L. americanus* has been found south of its present range.

Lepus townsendii

MATERIAL.—Fused dentary pair with right P/3./4, M/1./2./3, left /I, P/3./4, M/1./2 (BYUPV 5488), right dentary with M/1./2 (BYUPV 5467), right dentary with /I (BYUPV 5533), left dentary with all teeth (BYUPV 5442), left dentary with /I, P/3./4, M/1./2 (BYUPV 5484), 5 left dentaries without teeth (BYUPV 5424, 5429, 5474, 5532, LACM 123657), anterior portion of left dentary without teeth (BYUPV 5439), 7 isolated right P/3's (BYUPV 5733, 5770–5772, 5793, 5796, 5802), 7 isolated left P/3's (BYUPV 5735, 5736, 5780, 5783, 5790, 5791, 5804). A partial left dentary with P/3 (BYUPV 5485), 28 dentaries lacking P/3 (BYUPV 5422, 5427, 5436, 5438, 5448, 5450, 5454, 5456, 5458, 5462, 5473, 5475, 5478, 5483, 5487, 5489, 5493, 5495, 5500–5502, 5524, 5527, 5530, 5531, 5540–5542), 7 isolated right P/3's (BYUPV 5617, 5732, 5745, 5768, 5774, 5778, 5792), and 5 isolated left P/3's (BYUPV 5716, 5775, 5776, 5801, 5809) show characteristics common to both *L. townsendii* and *L. californicus*.

DISCUSSION.—*Lepus townsendii* and *L. californicus* are distinguished from *Sylvilagus* and *L. americanus* by their large size. They are distinguished from each other by *L. townsendii* having a larger mean size (Fig. 4) and having less crenulation in the second reentrant angle of P/3 than *L. californicus* (Hibbard 1952). Miller (1976) observed *L. californicus* to have a highly crenulated P/3 in most, but not all, cases, and Hibbard (1944, 1963) noted that individual variation is very great. My observations and those of J. A. White (1984, pers. comm.) show that many individuals of these species cannot be distinguished by either size or the amount of crenulation in P/3; but statistical analysis can be used to estimate their relative abundance (Grayson 1977). Hibbard (1952) stated that the anterior part of P/3 is narrower in *L. townsendii* than in *L. californicus*, but, although I noticed variation in the narrowness and roundedness of the anterior P/3's, it did

not correlate with the amount of crenulation in the second reentrant angle of that tooth. BYUVP 5424, 5467, and 5474 have greater alveolar length (P/3-M/3) to diastema length ratios than any Recent leporid specimens measured (Fig. 4), but they fall closest in size, especially based on their large tooth row length, to *L. townsendii*.

Since 11 of the 43 measurable *Lepus* dentaries are larger than any modern *L. californicus* specimens measured (Fig. 4), and over half of the large *Lepus* P/3's from the assemblage show no crenulation (a very rare condition in *L. californicus*), it is clear that *L. townsendii* is well represented. Most of the 29 jaws that could be either *L. townsendii* or *L. californicus* are closer to the mean size of *L. townsendii*, and the isolated 13 P/3's of *L. townsendii* or *L. californicus* have slight crenulation in the second reentrant angle, yet are considerably less crenulated than the vast majority of *L. californicus* specimens. Since only two highly crenulated P/3's clearly belonging to *L. californicus* (listed below) were found, most of these 13 P/3's with intermediate crenulation probably belong to *L. townsendii*. Based on this information I estimate that the ratio of *L. townsendii* to *L. californicus* specimens from the Crystal Ball Cave assemblage is about 10 to 1.

Grayson (1977) stated that *L. townsendii* is a more northern species and inhabits higher elevations and more grassy habitats than *L. californicus*, which prefers dryer shrubby areas. With *Sylvilagus*, the more northern species is represented in the assemblage, and the more southern species is not. This is also the trend with *Lepus*. Hall (1981) reported *L. townsendii* in the area of Crystal Ball Cave but Durrant (1952), in a more detailed map, did not. Both reported *L. californicus* throughout the Bonneville Basin area. I have seen numerous *L. californicus* around Gandy but never a *L. townsendii*, and J. C. Bates (1984, pers. comm.) reported never noticing any *L. townsendii* but seeing numerous *L. californicus*. This difference between the fossil and living species at Gandy suggests that climatic boundaries have shifted northward in latitude and upward in elevation since the Pleistocene. Grayson (1977), using both fossil and Recent data, demonstrated that *L. californicus* increased in number at the expense of *L.*

townsendii during the Recent and that it became the more dominant species in the Great Basin 5,000 to 7,000 Y.B.P. Although the ecological and adaptational differences between these two species are not fully understood, Grayson (1977) attributed this change to a post-Pleistocene warming trend. The species shift indicated by the Crystal Ball Cave assemblage reiterates the data presented by Grayson (1977).

Lepus californicus

MATERIAL.—Right P/3 (BYUVP 5781), left P/3 (BYUVP 5734). Twenty-nine dentaries and 13 other P/3's (listed under *L. townsendii*) show characters found in both *L. townsendii* and *L. californicus*. A left dentary with /I (BYUVP 5430) falls within the size range of *L. americanus* and *L. californicus*.

DISCUSSION.—*Lepus californicus* differs from *L. townsendii* in having a smaller mean size (Fig. 4) and a more crenulated second reentrant angle in P/3 as discussed above. The two P/3 specimens listed above have more crenulation than was seen in eight Recent *L. townsendii* specimens but are typical of *L. californicus*. The 13 P/3s of either *L. townsendii* or *L. californicus* (listed and discussed above) show less crenulation than the vast majority of *L. californicus* specimens studied, but some of them could represent *L. californicus* since crenulation in the P/3 is not always present (Miller 1976). *Lepus californicus* is presently the most common lagomorph around Crystal Ball Cave (J. C. Bates 1983, pers. comm.), so its poor representation in the fossil assemblage suggests that it has only recently become abundant there.

Order Rodentia Family Sciuridae *Marmota flaviventris*

MATERIAL.—Anterior portion of skull with right M1/2,3/, left M1/3/ (BYUVP 6528), anterior portion of skull without teeth (LACM 123663), dentary pair with right M1/3 (BYUVP 6536), right dentary with P/4, M1/3 (LACM 123665), right dentary with M1/2,3 (BYUVP 6543), right dentary with M2/3 (BYUVP 6621), right dentary with M/3

(BYUVP 6620), left dentary with /1, M1/.2/.3 (BYUVP 6477), left dentary with M1/.2/.3 (LACM 123669). Another 70 partial maxillae (some with teeth), 70 partial dentaries (some with teeth), and approximately 300 isolated cheek teeth (BYUVP 6476, 6478–6518, 6520–6527, 6529–6535, 6537–6542, 6544–6605, 6607–6619, 6622–6648, LACM 123664, 123666–123668, 123670) are of *Marmota* and compare favorably with *M. flaviventris*.

DISCUSSION.—*Marmota* is distinctly larger than other living sciurids (Hall 1981) but distinctly smaller than the extinct *Paenemarmota* (Repenning 1962). *Marmota flaviventris* is distinguished from *M. monax* by its anteriorly divergent upper tooth rows and from *M. caligata*, *M. olympus*, and *M. vancouverensis* by its smaller size (Hall 1981). *Marmota flaviventris* is also distinguished from these other species by its less massive dentition, M3/ being longer than it is wide, and M/3 having a triangular rather than a quadrangular outline (Logan 1983). Hay (1921) named *M. arizonae* based on a partial skull from northern Arizona and said it was similar to *M. flaviventris*. Since this specimen is probably Late Pliocene in age and the validity of the species is uncertain (Kurten and Anderson 1980), it is not considered a candidate for the Crystal Ball Cave specimens, all of which are indistinguishable from Recent *M. flaviventris*.

The presence of *M. flaviventris* in the Crystal Ball Cave assemblage represents a shift in the climate and vegetation of the area because this species now inhabits only much higher elevations in the Snake Range (Hall 1981, Mead et al. 1982) and does not live on or around Gandy Mountain (J. C. Bates 1983, pers. comm.). Hall (1946) reported fossil *M. flaviventris* from several caves far south of the present range of this species. Zimina and Gerasimov (1969) proposed that the marmot greatly expanded its distribution and numbers under Late Pleistocene periglacial conditions for which it was well adapted, but it has since diminished its range significantly. *Marmota flaviventris* is not a cave-dwelling species, so its great abundance in the Crystal Ball Cave assemblage suggests that it once lived on Gandy Mountain in large numbers, strongly supporting the hypothesis of Zimina and Gerasimov (1969).

Spermophilus townsendii

MATERIAL.—Anterior portion of skull with both I's (BYUVP 6060), partial skull with right P4/, M1/.2/ (BYUVP 6255), partial skull without teeth (BYUVP 6462), 7 right dentaries with all teeth (BYUVP 6107, 6109, 6141, 6282, 6284, 6326, 7256), and 2 left dentaries with all teeth (BYUVP 6421, 6433). Another 439 partial maxillae (some with teeth), 562 partial dentaries (some with teeth), and approximately 4,000 isolated cheek teeth compare favorably with *S. townsendii*.

DISCUSSION.—*Spermophilus townsendii* has the smallest mean size of any North American species of *Spermophilus* and is also slightly smaller than *Ammospermophilus leucurus* (Hall 1981). *Spermophilus* also differs from *Ammospermophilus* by having distinctly larger masseteric tubercles just anterior to the upper tooth rows (Hall 1981). The three partial skulls listed above and many of the partial maxillae without teeth have large masseteric tubercles that distinguish them from *Ammospermophilus*. All the specimens listed above compare best in size with *S. townsendii*, but some of those only referred to this species are probably *Ammospermophilus*. Kurten and Anderson (1980) listed 13 extinct species of *Spermophilus*, but the only one close enough in size and age of deposits to the Crystal Ball Cave specimens to be considered is *S. taylora*, named by Hay (1921) and based on a single specimen from Texas. Kurten and Anderson (1980) considered this a doubtful species and most likely a synonym of *S. townsendii*. It is therefore not considered here.

The presence of a single species of *Spermophilus* at Crystal Ball Cave is a striking contrast to the five possible species recovered from Smith Creek Cave in subequal numbers (Mead et al. 1982). These include *S. cf. townsendii*, *S. variegatus*, and *S. cf. lateralis*, which still inhabit the Snake Range, and *S. cf. richardsonii* and *S. cf. beldingi*, which have been extirpated but still inhabit Utah and/or Nevada (Hall 1981). The reason for this difference may be that Smith Creek Cave is at the base of 3,673 m (12,050 foot) Mount Moriah and at the edge of the flat open Snake Valley, an area of diverse niches in contact with several diverse environments even now, and certainly an area across which climatic

boundaries crossed many times during the Pleistocene. Gandy Mountain, on the other hand, is only a small hill far out in Snake Valley, the area most favorable to *S. townsendii* (Hall 1946), and is isolated from the main Snake Range by 10 km (6 miles) of flat valley.

The abundance of *Spermophilus townsendii* fossils at Crystal Ball Cave suggests that this squirrel lived around Gandy Mountain in large numbers for a long time, probably since fossils started accumulating in the cave. Durrant (1952) said this species is well suited to the western Utah desert and is particularly abundant around springs. Hall (1946) told how *S. townsendii* was a traditional food for native American Indians. *Spermophilus townsendii* is not a cave-dwelling animal as is *Neotoma*, and yet it is over twice as abundant as *Neotoma* in the assemblage (contrary to my earlier statement that *Neotoma* was the best represented genus, Heaton 1984). *Neotoma* has a much more restricted niche than *Spermophilus* and is never found in large numbers. Since squirrels are very unlikely to venture deep into caves, all the specimens must have been brought in by wood rats and/or small carnivores. It is interesting that fossil deposition occurred so rapidly, even deep in this isolated cave, that an outside species is better represented than the primary cave-dwelling species. J. C. Bates (1984, pers. comm.) reported seeing no squirrels on Gandy Mountain and only a few in the surrounding valley in the many years he has lived in Gandy. This, in contrast to its abundance as a fossil, suggests that *S. townsendii* reduced its numbers at the close of the Pleistocene in Snake Valley.

Ammospermophilus cf. *leucurus*

MATERIAL.—Right maxilla without teeth (BYUVP 8295), 2 left maxillae without teeth (BYUVP 8296, 8297). Some of the 439 maxillae, 562 dentaries, and approximately 4,000 isolated cheek teeth listed under *Spermophilus townsendii* probably also belong to this taxon.

DISCUSSION.—*Ammospermophilus* is distinguished from *Spermophilus* by its smaller masseteric tubercles and its less robust lower cheek teeth (Hall 1981). *Ammospermophilus*

leucurus now lives around Gandy Mountain, but *A. harrisi*, *A. interpres*, *A. insularis*, and *A. nelsoni*, the other four extant species, occur only south of Utah (Hall 1981), so the Crystal Ball Cave specimens are referred to *A. leucurus* although no character could be found to rule the others out.

According to Durrant (1952) *A. leucurus* commonly occurs with *S. townsendii* but has a more restricted habitat, preferring rocky terrains. *Ammospermophilus* is best adapted for high temperatures (Vaughan 1972), and its low abundance in the assemblage compared to *Spermophilus townsendii* suggests that it has not inhabited the area as long, at least not in its present abundance. With summers becoming hotter and drier at the close of the Pleistocene, *Ammospermophilus* may have increased its numbers at the expense of *Spermophilus* in Recent times.

Eutamius minimus

MATERIAL.—Right dentary with P/4, M/1./2 (BYUVP 6812), 3 right dentaries with P/4, M/1 (BYUVP 6171, 6210, 6755), left dentary with all teeth (BYUVP 6190).

DISCUSSION.—*Eutamius* has two premolars in each maxilla, whereas *Tamias* has only one. *Eutamius minimus* is the smallest species of *Eutamius* and has a narrower and squarer P/4 than *E. dorsalis* or *E. umbrinus*. All the specimens listed above match *E. minimus* with respect to the P/4 and are smaller than the other species. *Eutamius minimus* and *E. dorsalis* live in the region of Crystal Ball Cave, and *E. umbrinus* lives higher in the Snake Range and westward into Nevada (Hall 1981). *Eutamius minimus* was also recovered from Smith Creek Cave (Mead et al. 1982). *Eutamius minimus* inhabits diverse habitats from deserts to forests, so its presence in the assemblage is not surprising.

Eutamius dorsalis

MATERIAL.—Right dentary with P/4, M/1./2./3 (BYUVP 6233), right dentary with P/4, M/1 (BYUVP 6257), 2 right dentaries with M/1 (BYUVP 5974, 6304), 2 left dentaries with M/1 (BYUVP 6129, 6134). Three partial right maxillae with M1/ (BYUVP 6064, 6288, 6295) and a partial left maxilla with M1/ (BYUVP 6000) also compare favorably with this species.

DISCUSSION.—*Eutamias dorsalis* is distinctly larger than *E. minimus* and slightly larger than *E. umbrinus* (Mead et al. 1982). It has a distinct isolated mesoconid on M/1 that is lacking in *E. umbrinus* and is part of an ectolophid in *E. minimus* (Miller 1976). The M/1's of the six dentaries listed above match *E. dorsalis* in this character, and the four maxillae listed above match best in size with *E. dorsalis* but cannot be positively distinguished from *E. umbrinus*. Of the larger chipmunks, only *E. cf. umbrinus* was reported from Smith Creek Cave (Mead et al. 1982), and I have found only *E. dorsalis* in Crystal Ball Cave. Their present ranges help explain this difference since *E. umbrinus* only inhabits the Snake Range west of Crystal Ball Cave and *E. dorsalis* inhabits the entire range (Hall 1981). Their ranges show that *E. umbrinus* is more isolated in areas of high elevation and more commonly absent from the areas once covered by Lake Bonneville.

Family Geomyidae
Thomomys umbrinus

MATERIAL.—Anterior portion of skull with both I's (BYUVP 6656), anterior portion of skull with left I/ (LACM 123672), right dentary with I/I, P/4, M/1 (BYUVP 6657), left dentary with P/4 (BYUVP 8283). Four palates without teeth (BYUVP 6653, 6654, 6664, 6665), 4 right dentaries without cheek teeth (BYUVP 6660, 6663, 6666, 8281), and 8 left dentaries without cheek teeth (BYUVP 6655, 6658, 6659, 6662, 6681, 7009, 7010, 8282) also compare favorably with this species.

DISCUSSION.—*Thomomys* is distinguished from other North American geomyids by the absence of a superficial groove on the anterior face of the upper incisors (illustrations in Hall 1981), and none of the I's listed above have this groove. *Thomomys umbrinus* differs from *T. talpoides* and *T. monticola*, the only other species of *Thomomys* living in Nevada, Utah, or surrounding areas, by having a sphenoidal fissure, by not having the palatine foramina fully anterior to the anterior openings of the infraorbital canals (Durrant 1952), and by the absence of a lingual indentation in the anterior lobe of P/4 (Hall 1946). The two *Thomomys* skulls from Crystal Ball Cave have the sphenoidal fissure, and their palatine foramina are

fully anterior to the infraorbital canals. The two P/4's also lack the lingual indentation as in *T. umbrinus*. My observations and also those of Hall (1946, Fig. 308–321) indicate that *T. umbrinus* has a larger mean size than the other two species mentioned (contrary to Bergman's rule), and all the Crystal Ball Cave specimens compare best in size with the larger *T. umbrinus*.

Thomomys umbrinus is the only geomyid currently inhabiting the Snake Range, and it is a southern species, ranging from Nevada and Utah southward into Mexico (Hall 1981). *Thomomys bottae* and *T. townsendii* are now considered as subspecies of *T. umbrinus* (Hall 1981). *Thomomys talpoides*, which inhabits mountain ranges to the east and west of the Snake Range, has Nevada and Utah as almost its southern boundary and extends northward into Canada. *Thomomys talpoides* tends to inhabit higher elevations than *T. umbrinus* as well as higher latitudes. *Thomomys cf., talpoides* was the only geomyid reported from Smith Creek Cave (Goodrich 1965).

Hall (1946) pointed out that, although *T. umbrinus* is usually a lower-elevation species than *T. talpoides*, *T. umbrinus* is the only geomyid in the Snake Range and occurs at all elevations (but is less abundant at higher elevations than is *T. talpoides* at similar elevations in other ranges). Hall (1946) attributed this to antiquity of occupancy and proposed that *T. umbrinus*, having no competitors in the Snake Range, developed populations adapted to higher elevations. Since *T. umbrinus* was the species best adapted to the valleys surrounding the Snake Range, no species better adapted to higher elevations could pass through to their favorable habitat. This could explain why the Crystal Ball Cave assemblage suggests no northward range shift for species of *Thomomys* as it does for other groups such as lagomorphs. If Hall (1946) is right, the tentative assignment of the Smith Creek Cave specimen to *T. talpoides* (Goodrich 1965) must be in error. Another possibility is that predatory birds transported the specimen to the cave, but this seems unlikely since *T. talpoides* occurs only as close as 75 km (45 miles) to the northwest and 180 km (108 miles) to the east of Smith Creek Cave. Hall (1946) also pointed out that geomyids, as individuals, are extremely sedentary, and this could be the

cause of their slow invasion and northward retreat compared to other mammals.

Family Heteromyidae
Perognathus cf. *formosus*

MATERIAL.— Partial right maxilla with P4/ (BYUVP 6682), 2 right dentaries with P/4 (BYUVP 6859, 6879), 2 right dentaries with M/2 (BYUVP 6711, 6856), left dentary with all teeth (BYUVP 6697), left dentary with P/4, M/1 (BYUVP 6786), left dentary with P/4, M/2 (BYUVP 6115).

DISCUSSION.— *Perognathus longimembris*, *P. parvus*, and *P. formosus* now inhabit the Crystal Ball Cave area, and the closest other species range more than 250 km (150 miles) to the east and south (Hall 1981). Of the three local species, *P. longimembris* can be ruled out because its M/3 is distinctly smaller than its P/4 (Hall 1981), and the BYUVP 6697 has the opposite condition. *Perognathus parvus* and *P. formosus* are very similar dentally, and the Crystal Ball Cave specimens match well with both of them. *Perognathus formosus* has a larger mean size than *P. parvus*, and the Crystal Ball Cave specimens compare best in size with *P. formosus*, although *P. parvus* and several other western species cannot be ruled out. Miller (1979) referred all the *Perognathus* specimens found at Smith Creek Cave to *P. cf. parvus*, but, since the identification was tentative at both caves, it does not seem wise to speculate about a possible difference between the two assemblages with respect to this genus.

Microdipodops megacephalus

MATERIAL.— Right maxilla with P4/, M1/, 2/ (BYUVP 6695), right maxilla with P4/, M2/ (BYUVP 6781), right maxilla with M1/ (BYUVP 6709). Three partial right maxillae with P4/ (BYUVP 6669, 6674, 6797), a partial right maxilla with a partial M1/ (BYUVP 6759), a right dentary with I/, P/4, M/1 (BYUVP 6693), 2 right dentaries with P/4 (BYUVP 6795, 6860), and a left dentary with P/4 (BYUVP 6708) are of *Microdipodops* and compare favorably with *M. megacephalus*.

DISCUSSION.— *Microdipodops* is similar to *Perognathus* but can be distinguished dentally by the molars having a single enamel loop

as opposed to the biloph nature of *Perognathus* molars. The P/4's are also distinct in being more hypsodont and having a straight posteriolabial border as opposed to the round and symmetrical nature of the *Perognathus* P/4's. *Microdipodops megacephalus* ranges throughout most of Nevada and into neighboring states including Utah, and it is currently found around Crystal Ball Cave (Hall 1981). *Microdipodops pallidus*, the only other species, occurs along the southern Nevada-California border more than 320 km (200 miles) southwest of Crystal Ball Cave (Hall 1981). *Microdipodops megacephalus* can be distinguished from *M. pallidus* by the latter's possessing a small notch in the labial side of M1/, and all the Crystal Ball Cave specimens possessing the M1/ are clearly *M. megacephalus*. *Microdipodops* cf. *megacephalus* was reported at Smith Creek Cave (Miller 1979), and all heteromyid taxa recovered were low in abundance as at Crystal Ball Cave. This low abundance is probably due to a low density in life, since even now they are rarely seen in the area.

Dipodomys microps

MATERIAL.— Two right dentaries with I/ (BYUVP 6672, 8284), left dentary fragment with P/4 (BYUVP 6676). Nine maxillae without teeth (BYUVP 5593, 6667, 6668, 6670, 6675, 6677–6680) and 2 right dentaries without teeth (BYUVP 6673, 6683) also compare favorably with this taxon.

DISCUSSION.— *Dipodomys* is distinctly larger than other heteromyid genera. *Dipodomys microps* is distinguished from other species of *Dipodomys* by having chisel-shaped lower incisors (anterior face flat) rather than awl-shaped lower incisors (anterior face round), and the incisors of BYUVP 6672 and 8284 are chisel-shaped. The P/4 of *D. microps* is also distinct in having a larger and more isolated anterior loph than that of *D. ordii* or *D. merriami* but not a complete separation of lophs as in *D. deserti*, and the P/4 of BYUVP 6676 clearly matches *D. microps*. The referred specimens also match perfectly with Recent *D. microps* but lack the diagnostic teeth. Of the four species of *Dipodomys* presently living in Utah and Nevada, *D. microps* and *D. ordii* are found in the Snake

Range and *D. merriami* and *D. deserti* occur more than 200 km (125 miles) to the south and west (Hall 1981). *Dipodomys microps* has a much smaller range than *D. ordii*, occurring only in Nevada and parts of surrounding states (Hall 1981). The *Dipodomys* specimens recovered from Smith Creek Cave (Miller 1979) were referred to *D. ordii* because they had awl-shaped lower incisors. This difference between the two assemblages is difficult to explain because the range differences between these species do not suggest distinct differences in habitat preference.

Family Cricetidae *Peromyscus maniculatus*

MATERIAL.—Right maxilla fragment with M1/2/ (BYUVP 6703), left maxilla with M1/2/3/ (BYUVP 6782), left maxilla fragment with M1/2/ (BYUVP 6771). Thirty-nine *Peromyscus* dentaries containing one or more molars compare favorably with *P. maniculatus* and *P. crinitus*.

DISCUSSION.—Of the six species of *Peromyscus* that inhabit Utah and Nevada, only *P. maniculatus*, *P. truei*, and *P. crinitus* currently live around Crystal Ball Cave (Hall 1981). *Peromyscus maniculatus* was captured live inside the cave by the author in 1982 and 1983. *Peromyscus* fossils from Smith Creek Cave were not identified to the species level (Goodrich 1965, Mead et al. 1982, Miller 1979). Dental characters that distinguish species of *Peromyscus* are few and not always reliable. *Peromyscus maniculatus* and *P. truei* belong to the subgenus *Peromyscus*, which has accessory tubercles or enamel loops on the labial side of M1/ and M2/; *P. crinitus* belongs to the subgenus *Haplomyomys*, which lacks these features (Hall 1981). I found this character to be quite reliable, and the specimens listed above all have prominent cusps on M1/ and M2/. In further refinement of this character, Miller (1971, 1976) was able to separate *P. maniculatus* from all other western species of *Peromyscus* by the presence of an anteroconule on M1/ with direct attachment to the anterocone rather than being joined to it by a distinct loph as in *P. truei*. Specimens listed above fit *P. maniculatus* in this respect. Species of the subgenus *Haplomyomys* usually lack the anteroconule entirely (Hall 1981,

Miller 1971, 1976). Unfortunately, excessive wear on the teeth erases this character.

Of the 40 *Peromyscus* dentaries containing one or more molars, 39 compare best in size with the smaller *P. maniculatus* and *P. crinitus*, but no character could be found to separate these species based on dentaries. Miller (1976) found the P/3's of *P. maniculatus*, *P. crinitus*, and *P. eremicus* to be relatively more reduced than *P. boylii* and *P. truei*. The 8 Crystal Ball Cave *Peromyscus* dentaries containing M/3 tend to have M/3 relatively reduced as in *P. maniculatus*, *P. crinitus*, and *P. eremicus*, and in size all the 39 dentaries listed above compare best in size with the smaller *P. maniculatus* and *P. crinitus*.

Peromyscus cf. *crinitus*

MATERIAL.—Right maxilla with M1/2/ (BYUVP 6780), left maxilla with M1/2/ (BYUVP 6769), left maxilla with M1/ (BYUVP 6715). Thirty-nine *Peromyscus* dentaries containing one or more molars compare favorably with *P. maniculatus* and *P. crinitus*.

DISCUSSION.—These specimens lack accessory tubercles and enamel loops on the two principal outer angles of M1/ and M2/, so they probably belong to the subgenus *Haplomyomys* (Hall 1981). Of the two species of *Haplomyomys* found in Utah, *P. crinitus* and *P. eremicus*, the Crystal Ball Cave specimens compare better in size with the smaller *P. crinitus* (although there is considerable overlap). Some of the 39 dentaries discussed under *P. maniculatus* (above) could also belong to this species since no character was found to distinguish them based on dentaries. *Peromyscus crinitus* is presently found around the cave, but *P. eremicus* ranges only as close as 225 km (135 miles) to the south (Hall 1981), further suggesting that these specimens are *P. crinitus*.

Peromyscus cf. *truei*

MATERIAL.—Left dentary with M/1 (BYUVP 6718).

DISCUSSION.—*Peromyscus truei* is the largest species of *Peromyscus* living in Utah and Nevada (Durrant 1952, Hall 1981), and the M/1 listed above compares well in size with this species and is larger than the mean

size of *P. eremicus* and *P. boylii* and distinctly larger than any *P. maniculatus* or *P. crinitus* M1's examined. Identification is based only on size since no other character could be found to distinguish M1's of *Peromyscus*. This species is found throughout the Great Basin, so its presence in the assemblage is not surprising.

Neotoma lepida

MATERIAL.—Partial skull without teeth (LACM 123671), 2 partial right maxillae with M1/ (BYUVP 7045, 7065), left maxilla with M1/ (BYUVP 7154), partial left maxilla with M1/ (BYUVP 7246).

DISCUSSION.—*Neotoma lepida* and *N. cinerea* are the only species of *Neotoma* that presently inhabit the Snake Range (Hall 1946, 1981). Of three wood rats that I trapped in Crystal Ball Cave and two elsewhere on Gandy Mountain in 1982 and 1983, all were *N. lepida*. I did trap a *N. cinerea* in another cave in the Snake Range 35 km (22 miles) south of Crystal Ball Cave, so they are known to inhabit caves in the area. Miller (1979) reported both *N. lepida* and *N. cinerea* from Smith Creek Cave but did not comment on their relative abundance. Of these two species, *N. cinerea* is much more boreal than *N. lepida*, having a more northern range and being found at higher elevations (Finley 1958, Hall 1946, 1981). Durrant (1952) and Hall (1981) also reported *N. albigula*, *N. mexicana*, and *N. stephensi* living in Utah but far to the south and east of Crystal Ball Cave.

Neotoma cinerea is usually distinguishable from *N. lepida* by its larger size and deeper anterolabial reentrant angle on M1/ (Finley 1958). According to Hall (1946), the maxillary alveolar length is always 8.8 mm or less in *N. lepida* and 9.1 mm or more in *N. cinerea* for the Nevada subspecies, and Finley (1958) reported only a slight overlap for the Colorado subspecies. The three other Utah species of *Neotoma* are intermediate in size between *N. lepida* and *N. cinerea*, and *N. albigula* has the M1/ pattern of *N. lepida* whereas *N. mexicana* and *N. stephensi* have the M1/ pattern of *N. cinerea* (Finley 1958). Because these are the most diagnostic characters, only maxillae with M1/ and/or a measurable alveolar length were considered.

The Crystal Ball Cave specimens listed above compare best in size with *N. lepida*, the only species of *Neotoma* known to presently inhabit the cave. Maxillary alveolar lengths of *Neotoma* specimens from the cave show a strongly bimodal distribution, suggesting that *N. albigula*, *N. mexicana*, and *N. stephensi* are not represented since they are intermediate in size between *N. lepida* and *N. cinerea*. The shallow anterolabial reentrant angle of the M1's also compares favorably with *N. lepida*. The scarcity of *N. lepida* specimens in the assemblage suggests that this species probably has not always inhabited the cave as it does now.

Neotoma cinerea

MATERIAL.—Anterior portion of skull with both I/, M1/2/ (BYUVP 7384), maxilla pair with all teeth except left I/ (BYUVP 7281), maxilla pair with right M1/2/3/, left M1/2/ (BYUVP 7282), maxilla pair with both M1/2/ (BYUVP 7067), maxilla pair with right M1/2/ (BYUVP 7015), maxilla pair with left M1/ (BYUVP 7213), 9 right maxillae with M1/2/3/ (BYUVP 7136, 7149, 7158, 7167, 7214, 7248, 7254, 7314, 7320), 3 right maxillae with M1/ (BYUVP 7273, 7316, 7330), 25 partial right maxillae with M1/ (BYUVP 7014, 7018, 7024, 7038, 7046, 7104, 7114, 7125, 7134, 7138, 7147, 7170, 7177, 7180, 7182, 7197, 7204, 7216, 7242, 7247, 7249, 7276, 7344, 7348, 7349), 10 right maxillae without teeth (BYUVP 7255, 7343, 7353, 7367, 7377, 8286–8290), 7 left maxillae with M1/2/3/ (BYUVP 7095, 7212, 7250, 7257, 7274, 7376, 7379), 4 partial left maxillae with M1/2/ (BYUVP 7101, 7174, 7179, 7324), partial left maxilla with M1/2/ (BYUVP 7017), 34 partial left maxillae with M1/ (BYUVP 7021, 7061, 7062, 7072, 7073, 7087, 7099, 7106, 7133, 7140, 7142, 7144, 7145, 7151, 7162–7164, 7172, 7175, 7183, 7189, 7200, 7205, 7217, 7220, 7225, 7267, 7300, 7317, 7318, 7322, 7351, 7362, 7371), 6 left maxillae without teeth (BYUVP 7171, 7346, 8291–8294). Another approximately 200 maxillae, 200 dentaries, and 2000 isolated molars compare best with this species.

DISCUSSION.—*Neotoma cinerea* is recognized by its large size and deep anterolabial reentrant angle on M1/ as discussed above.

Neotoma cinerea has the largest mean size of any species of *Neotoma*, and all the specimens listed above match Recent *N. cinerea* in size and have the deep anterolabial reentrant angle on M1/ when this tooth is present. This makes *N. cinerea* the second best represented species in the Crystal Ball Cave assemblage after *Spermophilus townsendii*. The fact that *N. cinerea* is abundant in the assemblage but not found in the cave now, whereas *N. lepida* is rare in the assemblage but now the only wood rat living in the cave, suggests that a replacement of *N. cinerea* by *N. lepida* has recently taken place in the area. The great abundance of *N. cinerea* remains at sites 1 and 2 of Crystal Ball Cave also helps substantiate my hypothesis that wood rats were the primary means of transporting fossils, especially of large mammals, into the cave. The dominance of *N. cinerea* over *N. lepida* in the assemblage suggests that *N. cinerea* was the primary species involved in this transport.

The ecological differences between *N. cinerea* and *N. lepida* have significance both to the replacement of the former species by the latter and to the accumulation of fossils in the cave. Finley (1958), in his detailed study of Colorado wood rats, found den sites to be the most limited resource for all species. Since all wood rats prefer the same basic types of den sites, namely rocky crags and caves, multiple species are rarely found coexisting (Finley 1958). This suggests that, when conditions at Crystal Ball Cave reached a threshold where they favored *N. lepida* over *N. cinerea*, the replacement took place quickly. *Neotoma cinerea* prefers higher elevations and latitudes than *N. lepida*, and hot summers in arid regions seem to be a limiting factor for this species (Finley 1958, Hall 1981). The changing conditions that led to the replacement of *N. cinerea* by *N. lepida* may have been the increase in temperature and decrease in moisture at the close of the Pleistocene, the shift in vegetation caused by it, or both. Regarding food, Finley (1958) stated that *N. cinerea* prefers soft-leaved shrubs, forbs, and montane conifers, whereas *N. lepida* prefers xerophytic shrubs, forbs, cacti, and shrubby trees.

Species of *Neotoma* differ somewhat in den preferences and collecting habits. Finley (1958) stated: "Dens of *N. cinerea* are usually in high vertical crevices in cliffs or caves,

whereas those of . . . *N. lepida* are usually in low horizontal crevices or under boulders or large fallen blocks. Dens of [*N.*] *cinerea* usually contain larger accumulations of sticks and bones." That *N. cinerea* collects more material, especially bone, is very significant since I consider wood rats as the primary mechanism of fossil deposition at Crystal Ball Cave. This suggests that the rate of bone deposition decreased when *N. lepida* replaced *N. cinerea*, and it helps explain why many elements of the present local fauna are so poorly represented in the assemblage and why all the dated fossils are Late Pleistocene rather than Recent in age.

A replacement of *N. cinerea* by *N. lepida* parallels the replacement of *Sylvilagus nuttallii* by *S. audubonii* and *Lepus townsendii* by *L. californicus* (discussed above) and helps confirm that a warming trend took place in the recent past. Although *N. cinerea* still lives in the area, it seems to have been driven to higher elevations in the Snake Range.

Ondatra zibethicus

MATERIAL.—Palate without teeth (BYUVP 7383), partial right dentary with anterior $\frac{2}{3}$ of M1 (BYUVP 7391).

DISCUSSION.—*Ondatra* is easily distinguished from other microtine rodents by its large size combined with rootless molars. *Ondatra zibethicus* is now considered the only extant species of *Ondatra* (Hall 1981), and the Crystal Ball Cave specimens are indistinguishable from this species. A number of fossil species have been named, but there is considerable confusion about their status (Miller 1976). All the extinct species considered valid by Semken (1966) and Nelson and Semken (1970) are smaller than *O. zibethicus*. The Crystal Ball Cave dentary is almost as large as the largest *O. zibethicus* to which it was compared. The M1 is 7.9 mm long and 2.5 mm wide which best matches measurements taken from Wisconsinan-age *O. zibethicus* specimens (Nelson and Semken 1970). The palate is slightly smaller than the mean of *O. zibethicus* but well within its range of variation.

Ondatra zibethicus has not been reported living near Gandy but occurs as close as 56 km (35 miles) to the northeast and 160 km (100

miles) to the south (Hall 1981). Since *Ondatra* is a reliable indicator of permanent water (Nelson and Semken 1970), the retreat of Lake Bonneville and loss of perennial streams in the area probably lead to its extirpation from the Snake Range.

Microtus cf. longicaudus

MATERIAL.— Two left M3's (BYUVP 6940, 6981), 7 right M3's (BYUVP 8220–8226), 15 left M3's (BYUVP 7002, 8227–8241). Numerous other partial jaws and isolated molars cannot be distinguished from *Lagurus* but lack characters that would assign them to other species of *Microtus*, some of which are likely *Microtus* since over a third of the microtine M3's belong to *Microtus*. Among these are a partial skull with both M1/2 and the posterior incisive foramina (BYUVP 8285) and a right maxilla with M1/2 (BYUVP 6943).

DISCUSSION.— *Microtus* differs from *Lagurus*, the only other microtine of its size with rootless molars, in having 3 transverse loops on M3 rather than 4 prisms, some of which are closed triangles, and in having a large semicircular posterior loop on M3 rather than a simple elongate loop (Hall 1981). The 2 M3's and 22 M3's from Crystal Ball Cave listed above clearly match *Microtus* in this respect. There are many species of *Microtus*, some of which have distinct dental characteristics and some of which do not.

The only two species of *Microtus* now inhabiting the Snake Range are *M. longicaudus* and *M. montanus*, and no character could be found to distinguish them dentally. The incisive foramina of *M. longicaudus* are not constricted posteriorly as are those of *M. montanus*, but they differ from those of *Lagurus* only in having slightly curved rather than straight external margins. Since only the posterior end of the incisive foramina are found on skulls that could be *Microtus* from Crystal Ball Cave, skulls of *M. longicaudus* in the collection are indistinguishable from *Lagurus*. Of 13 skulls containing incisive foramina that may be *Microtus*, 2 have constricted incisive foramina as in *M. montanus* (listed below), and 11 compare well with *M. longicaudus* and *Lagurus*.

Three other species of *Microtus* presently occur in Utah but not in the Snake Range: *M.*

pennsylvanicus and *M. richardsoni* in the central mountain ranges and *M. mexicanus* in the southwestern corner of the state. *Microtus pennsylvanicus* has a posterior loop on M2/ not found in other species, and this character was only found on one specimen (listed below). *Microtus richardsoni* is distinctly larger than the other species described here, and none of the microtine specimens from Crystal Ball Cave are large enough to compare with it. *Microtus mexicanus* is dentally indistinguishable from *M. montanus* and *M. longicaudus*, and its incisive foramina are identical to *Lagurus* and similar to *M. longicaudus*.

The specimens listed above are identical to Recent specimens of *M. longicaudus*, *M. mexicanus*, and more distant ranging species. But since *M. longicaudus* presently occurs at Crystal Ball Cave whereas *M. mexicanus* occurs more than 400 km (250 miles) to the southeast (Hall 1981), and because the general trend in the region is for range boundaries to be migrating northward, the Crystal Ball Cave specimens (except the few discussed below) are referred to *M. longicaudus*.

Microtus cf. montanus

MATERIAL.— Two partial palates without teeth, which include the posterior end of the incisive foramina (BYUVP 8218, 8219).

DISCUSSION.— *Microtus montanus* is the only microtine of its size presently occurring in Utah or Nevada with incisive foramina that abruptly constrict posteriorly and are narrower posteriorly than anteriorly. The posterior ends of the incisive foramina in these two specimens are too narrow to be *M. longicaudus*, *M. pennsylvanicus*, *M. mexicanus*, or *Lagurus curtatus*. *Microtus townsendii* and *M. oregoni* also have incisive foramina like *M. montanus*, but they both occur only along the Pacific Coast from northern California to southern British Columbia. Since *M. montanus* presently occurs in the Snake Range (Hall 1981), the Crystal Ball Cave specimens are referred to it. *Microtus montanus* tends to occur at higher elevations than other species of *Microtus* in Utah (Durrant 1952), so its presence in the assemblage suggests that conditions at the cave during the Late Pleistocene may have been like those of higher elevations in the Snake Range now.

Microtus cf. pennsylvanicus

MATERIAL.— Partial skull with right M1/, 2/ (BYUVP 6973).

DISCUSSION.— *Microtus pennsylvanicus* is unique in having a rounded posterior loop behind the 4 closed angular sections of M2/. This single specimen from the assemblage has this posterior loop, but the loop is not completely closed off from the preceding triangle as in the Recent specimens to which it was compared. Since the distinguishing character is not fully developed, the specimen is only referred to *M. pennsylvanicus*. This species is not presently found in the Snake Range, but it occurs 190 km (114 miles) east of Crystal Ball Cave in the mountains of central Utah and is a northern species (Hall 1981). Considering the climatic shifts since the recession of Lake Bonneville, it is not unlikely that it could have inhabited the Snake Range during the Late Pleistocene.

Lagurus curtatus

MATERIAL.— Skull with right I/, M2/, 3/, left I/, M1/, 2/ (BYUVP 6899), left dentary with M1/, 2/, 3/ (BYUVP 6977), left dentary with M2/, 3/ (BYUVP 6986), 28 right M3's (BYUVP 8242–8270), 9 left M3's (BYUVP 8271–8280). Numerous partial jaws and isolated molars may be *L. curtatus* but cannot be distinguished from *Microtus longicaudus* (as discussed above).

DISCUSSION.— The differences between *Lagurus* and *Microtus* are discussed above. *Lagurus curtatus*, the only North American species of *Lagurus*, is distinguished from Old World representatives by having four instead of five closed triangles on M/3 and cement present in the reentrant angles of the molars (Hall 1981). This species presently occurs in the Snake Range and northward into Canada (Hall 1981). *Lagurus* specimens are nearly twice as abundant as those of *Microtus* in the assemblage, but, since no information on their Recent relative abundance or habitat differences could be found, it is difficult to understand the reason for this.

Order Carnivora
Family Canidae
Canis cf. latrans

MATERIAL.— Lower incisor (BYUVP 7459), right C/1 (LACM 123675), partial left M/1

(BYUVP 7460). The frontal region of a skull (LACM 123676) and an anterior fragment of a left dentary without teeth (BYUVP 7458) also compare favorably with this species.

DISCUSSION.— These specimens are indistinguishable from specimens of Recent *C. latrans*, generally recognized as the only species of coyote in the Pleistocene or Recent (Giles 1960). Dentally, *C. latrans* falls within the wide range of variation of the domestic dog, *C. familiaris* (Anderson 1968), so the possibility that the Crystal Ball Cave specimens are *C. familiaris* cannot be totally eliminated. Nevertheless, *C. latrans* is presently very abundant around the cave (J. C. Bates 1983, pers. comm., Hall 1981) and has been recognized from nearby Pleistocene assemblages that have better stratigraphic control (Kurten and Anderson 1972, Miller 1979), so there is no reason to believe it would not be found in the assemblage. Also, domestic dogs tend to have many more tooth malformations than coyotes (Anderson 1968), and none are seen in the Crystal Ball Cave specimens. Lack of human fossils and artifacts at Crystal Ball Cave makes domestic dogs less likely to be present than at sites that contain such remnants of human occupation. Although residents of Gandy have domestic dogs that sometimes roam on Gandy Mountain, the lack of any canid specimens in the assemblage that cannot be referred to native species also supports the conclusion that the Crystal Ball Cave specimens are *C. latrans*.

Canis cf. lupus

MATERIAL.— Partial right M1/ (BYUVP 7455), left P/1 (BYUVP 7457), posterior end of right M/1 (BYUVP 7456), left M/1 (LACM 123674), axis (LACM 123710).

DISCUSSION.— Identification of these canid fossils is based on their size, being substantially larger than *C. latrans* but considerably less robust than *C. dirus*. They do, however, fit within the large size range of *C. familiaris*, so the identification must be tentative. Goodrich (1965) reported *C. lupus* from Smith Creek Cave but did not describe the material. *Canis lupus* has been reported living in the Snake Range in Recent times (Hall 1981), although man has now reduced its range and numbers considerably.

Vulpes vulpes

MATERIAL.—Skull with right P1/2, 4/, left P4/, M2/ (BYUVP 8299), posterior portion of right maxilla with M1/2/ (BYUVP 7466), partial left maxilla with M1/2/ (BYUVP 7467), 2 right C1/s (BYUVP 7468, 7470), left C1/ (BYUVP 7469), right P4/ (BYUVP 7474), left P4/ (BYUVP 7471), right dentary with M/2 (BYUVP 7461), posterior portion of right dentary with P/4, M1/2 (BYUVP 7463), left dentary with M1/2 (BYUVP 7464), anterior portion of left dentary with M1/2 (BYUVP 7462), right P/4 (BYUVP 7475), left P/4 (BYUVP 7472). An anterior fragment of a right dentary without teeth (BYUVP 7465) and an anterior fragment of a left dentary without teeth (BYUVP 7476) also compare favorably with this species.

DISCUSSION.—*Vulpes* is distinguished from *Urocyon* by the configuration of the crest on the top of the skull and the lack of a prominent "step" on the posteroventral margin of the dentary. The ventral margin of the dentary of *Vulpes* curves upward posteriorly beginning at the posterior end of the tooth row, but in *Urocyon* it remains uncurved well behind the tooth row all the way to the "step." *Urocyon*, which now ranges from the cave site southward and throughout North America, is intermediate in size between *V. vulpes* and *V. velox*. Four of the Crystal Ball Cave specimens include the posterior dentary and lack the "step" characteristics of *Urocyon*, and all the Crystal Ball Cave specimens are larger than the largest *Urocyon* specimen examined but compare well in size and shape to *V. vulpes*.

Vulpes vulpes does not presently occur around Crystal Ball Cave but *V. velox* and *U. cinereoargenteus* do (J. C. Bates 1983, pers. comm., Hall 1981). The presence of the more northern *V. vulpes* but not the more southern *U. cinereoargenteus* in the cave assemblage represents a northward shift of the boundary between these two species. The ranges of *V. vulpes* and *U. cinereoargenteus* do overlap to a degree now, but in the western United States the overlap is not great, and where it does occur *V. vulpes* favors the higher elevations and *U. cinereoargenteus* the lower elevations (Hall 1981). Based on range maps in Hall (1981), the range of *V. vulpes* in the

western United States is quite scattered, suggesting that it is relictual and that this species is diminishing in numbers there. *Urocyon cinereoargenteus* has a distinct northern boundary across Utah and Nevada with no remnant populations, suggesting that this species has been making a northward invasion. The Crystal Ball Cave assemblage confirms that *U. cinereoargenteus* has been expanding its range at the expense of *V. vulpes*.

Vulpes velox

MATERIAL.—Left dentary with P/3 and partial M/1 (BYUVP 7477), posterior portion of left M/1 (BYUVP 7479). A partial left dentary with M/2 (BYUVP 7478) also compares favorably with this species.

DISCUSSION.—*Vulpes velox* and *V. macrotis* are now considered conspecific (Hall 1981). The dentary (BYUVP 7477) lacks the "step" of *Urocyon*, and the M/1 lacks a small cusplule found on the posterolabial margin of the main cusp of all the *Urocyon* specimens but none of the *Vulpes* specimens examined. The Crystal Ball Cave specimens listed above are smaller than *U. cinereoargenteus* but may be similar in size to the smaller *U. littoralis*, which is known only from islands along the coast of southern California (Miller 1971).

Since *V. velox* still lives around Crystal Ball Cave (J. C. Bates 1983, pers. comm.), its presence in the assemblage is not surprising. Its low frequency compared to the now extirpated *V. vulpes* suggests that it may not have always inhabited the area, may have inhabited it in much smaller numbers, or may have had a different microhabitat causing it to frequent the cave area less than *V. vulpes*. The ranges of *V. vulpes* and *V. velox* presently overlap to a degree, especially in the midwest, but in the western United States this overlap is small (Hall 1981). Although *V. velox* occurs in the Snake Range now, it is a more southern species than *V. vulpes*, so its northern range extensions may be of Recent age.

Family Mustelidae
Mustela cf. frenata

MATERIAL.—Left M1/ (BYUVP 7487), right dentary with P/2, 3/, M1/2 (BYUVP 7483), partial right dentary without teeth (BYUVP

7484), left dentary with M/1,2 (BYUVP 7488), left dentary with M/1 (BYUVP 7485), partial left dentary with M/1,2 (BYUVP 7486).

DISCUSSION.—All these *Mustela* specimens compare best in size with *M. frenata*, which presently lives around Crystal Ball Cave. The size range of *M. frenata* is overlapped by the smaller but more variable *M. erminea* (Kurten and Anderson 1980), which also ranges in the cave area (Hall 1981). The specimens could belong to *M. erminea* since this species is dentally similar to *M. frenata*. *Mustela rixosa* is always smaller and *M. nigripes* and *M. vison* are always considerably larger than the Crystal Ball Cave specimens. *Mustela frenata* was the most abundant mustelid at Smith Creek Cave, but *M. erminea* was also present (Miller 1979). Since all the Crystal Ball Cave specimens fall in the narrow size range of *M. frenata*, they are referred to this species.

Mustela cf. *vison*

MATERIAL.—Left M1/ (BYUVP 7482). A juvenile left dentary without teeth (BYUVP 7491) also compares well with this species.

DISCUSSION.—This isolated tooth was compared to a variety of Recent mustelids and other small carnivores and found most similar to *M. vison*. This is North America's largest extant species of *Mustela* (although the extinct sea mink, *M. macrodon*, was larger) and is distinctly larger than, but similar in shape to, *M. frenata* (described above). *Mustela vison* was recovered from Smith Creek Cave (Miller 1979) and presently occurs 160 km (100 miles) north and east of Crystal Ball Cave (Hall 1981), but it does not currently live in the Snake Range. This species requires lakes or streams to survive (Hall 1946), so its extirpated nature in the Snake Range may have been due to the recession of Lake Bonneville and/or loss of perennial streams in the area at the end of the Pleistocene.

Mustela vison is sometimes confused with *M. nigripes* since both are of similar size (Kurten and Anderson 1980), and no distinction in isolated molars could be found in the literature. *Mustela nigripes* is currently endangered, and no comparative material was available. It has never been reported from

western Utah or Nevada, so the Crystal Ball Cave specimens are referred to *M. vison*, which is known to have lived in the area.

Martes americana

MATERIAL.—Left dentary with M/1 (BYUVP 7480), left M/1 (BYUVP 7481). The anterior portion of a right dentary without teeth (BYUVP 7489) and the posterior portion of a right dentary without teeth (BYUVP 7523) probably also belong to this taxon.

DISCUSSION.—Anderson (1970), in her systematic review of the genus *Martes*, considered *M. nobilis* (found in four caves in Wyoming, Idaho, and northern California) to be a distinct species from *M. americana*. Of the two, *M. nobilis* is larger, and its lower carnassial has a relatively shorter trigonid. The lower canines of *M. nobilis* sometimes have faint grooves on the external surface not found in *M. americana* (Anderson 1970). The only other species of *Martes* presently living in Utah is *M. pennanti*, the fisher. It is considerably larger than *M. americana*, *M. nobilis*, and the Crystal Ball Cave specimens. Neither *M. americana* nor *M. pennanti* currently live in the Snake Range, but both occur in the mountains of central Utah and northward.

BYUVP 7480 is as large as the largest *M. americana* specimen to which it was compared, and, judging from the incisor socket, its incisor was slightly larger. The other specimens are the same size as most Recent *M. americana* specimens. Both lower carnassials match perfectly in shape with *M. americana* and do not show a relatively shorter trigonid, so they are assigned to *M. americana*. A right M1/ of *M. nobilis* was recovered from Smith Creek Cave (Miller 1979), but *M. americana* has never been reported. The ecological and chronological separation of these two species in the Snake Range is, therefore, problematic. Brown (1971) listed *M. americana* as one of eight species of boreal mammals that presently range in the Sierra Nevada and the Rocky Mountains but on none of the isolated Great Basin ranges in between. This citing demonstrates that *M. americana* did range at least as far east in the Great Basin as the Snake Range before becoming extirpated.

Brachyprotoma brevimala, sp. nov.

TYPE.—Anterior portion of skull including a complete palate except the most posterior



Fig. 5. Photographs of the type specimen of *Brachyprotoma brevimala* (BYUVP 7490) in palatal and right side view (3X).

(smallest) socket of each M1/ and extending posteriorly to include the entire anterior wall of the braincase (BYUVP 7490, Fig. 5). Only the right P4/ was found *in situ*, but a right and left M1/ (previously cataloged as BYUVP 7492 and 8298, respectively) fit perfectly into the sockets of the type specimen, where they have been permanently mounted. The type specimen is of a young adult based on complete fusion of the premaxillae, maxillae, nasals, and frontals and on lack of significant tooth wear. Both the skull and isolated M1/'s were recovered from site 1, channel A, Crystal Ball Cave, Millard County, Utah (Figs. 1 and 3) by Wade E. Miller and party 19 March 1977. The type specimen is housed at the Brigham Young University Vertebrate Paleontology Laboratory.

DIAGNOSIS.—*Brachyprotoma brevimala* has a short face and a maxillary tooth formula of I3/-3/, C1/-1/, P2/-2/, M1/-1/ as in *B. obtusata*. Face and maxillary dental measurements average 15% smaller than those of *B. obtusata*. *Brachyprotoma brevimala* is distinguished from *B. obtusata* by P4/ being transversely narrower and having a more posteriorly directed lingual cusp and by M1/ being more reduced and distinctly shorter anteroposteriorly. In other known characters *B. brevimala* is equivalent to *B. obtusata*. *Brachyprotoma brevimala* has the most re-

duced P4/ and M1/ and the shortest maxilla of any known skunk, and it is for this latter character that the species is named.

DESCRIPTION.—The maxillary dental formula of I3/-3/, C1/-1/, P2/-2/, M1/-1/ is known among the mustelids only in two genera of skunks, *Conepatus* and *Brachyprotoma* (although I found one abnormal Recent *Spilogale putorius* specimen with this formula). The Crystal Ball Cave specimen is clearly a skunk (subfamily Mephitinae) based on the presence of only two pairs of upper premolars (mephitines have two or three, all other mustelids have three or four), the small size (only the subfamilies Mustelinae and Mephitinae have such small adult individuals), the lingual cusp of P4/ extending from the middle of the tooth (as opposed to the more anterior extension in the mustelines), M1/ being anteroposteriorly shorter labially than lingually (mustelines have the opposite condition), and the internal nares extending almost as far anteriorly as the posterior end of the tooth row (they are much more posterior in mustelines).

Compared to extant mephitines, the Crystal Ball Cave specimen represents an individual of similar size to *Spilogale* but much smaller than *Conepatus* and *Mephitis*. The palate is shorter and wider than that of *Spilogale putorius*, but the interorbital breadth

shows that the type specimen represents a larger individual than the average *S. putorius*. The P4/ is similar to *Spilogale*, differing only in having the lingual cusp slightly more posterior, but it is proportionally much narrower than the P4/ of *Mephitis* and *Conepatus*. The M1/s are proximo-distally shorter than any of the living mephitines (especially *Conepatus* and *Mephitis* that have large square M1/s) and are closest to *Spilogale* in shape and cusp pattern. The rostrum of the type specimen is shorter than that of *Spilogale*, matching that of *Conepatus* in proportions. The external nare is steep as in *Conepatus*, but it is relatively small and round as in *Spilogale*. Both infraorbital canals are single rather than double or triple, a species-diagnostic character in *Conepatus* (Hall 1981) but variable in *Mephitis* and *Spilogale*.

In addition to the three extant genera, three Pleistocene skunk genera have been named: *Buisnictis*, *Brachyprotoma*, and *Osmotherium* (Kurten and Anderson 1980). *Osmotherium* can be ruled out since it is large and very similar to *Mephitis* (Kurten and Anderson 1980), the living skunk genus that is most distinct from the Crystal Ball Cave specimen. Both *Buisnictis* and *Brachyprotoma* are small and have proportionally short jaws like the Crystal Ball Cave specimen. *Buisnictis* has been recovered from Late Pliocene deposits of southwestern Idaho (Bjork 1970) and Middle Pliocene to Early Pleistocene deposits of Kansas and Oklahoma (Hibbard 1941, 1950, 1954), but it has no record in the Late Pleistocene or Recent. *Buisnictis* has a short jaw with crowded premolars, but it differs from the Crystal Ball Cave specimen in having three pairs of upper premolars instead of two (Kurten and Anderson 1980). Based on an illustration by Hibbard (1954), the P4/ of *Buisnictis* has its lingual cusp extending from the anterior part of the tooth as in the mustelines, and the M1/ is distinctly longer than that of the Crystal Ball Cave specimen. These morphologic and age differences show that the Crystal Ball Cave specimen is distinct from *Buisnictis*.

The Crystal Ball Cave specimen matches the genus *Brachyprotoma* in having short jaws, only two pairs of upper premolars, P4/ and M1/ similar in shape and cusp pattern to *Spilogale*, and in the age of deposits in which they have been recovered. Until recently

Brachyprotoma was only known from a few Early Pleistocene to Early Recent age cave deposits in the eastern United States. But during the period of this study, P. M. Youngman (1984, pers. comm.) recovered several *Brachyprotoma* specimens from two fossil sites in the Yukon Territory of Canada. Although no previous *Brachyprotoma* specimens have been reported closer than 1880 km (1130 miles) from Crystal Ball Cave, morphology clearly allies the Crystal Ball Cave specimen with this genus. But there are specific differences between the Crystal Ball Cave specimen and other skulls that have been assigned to the genus *Brachyprotoma*. To test the amount of variation to be expected within a species of skunk, 73 specimens of Recent *Spilogale putorius* were measured, 60 from the Harvard University Museum of Comparative Zoology and 13 from the Brigham Young University Monte L. Bean Museum. *Spilogale putorius* makes a good standard for the expected individual variation in species of *Brachyprotoma*, both because *Spilogale* is probably the most closely related extant genus to *Brachyprotoma* and because *S. putorius* borders on being divisible into multiple species (although most workers presently consider it a single species). Based on the great amount of variation seen between the Crystal Ball Cave specimen and other skulls assigned to the genus *Brachyprotoma* compared with the amount of variation seen among individuals of *S. putorius*, I believe the Crystal Ball Cave specimen warrants the status of a new species.

The *B. brevimala* type is smaller than specimens of *B. obtusata* in most measured characters, averaging about 15% smaller (Table 3). The greatest differences occur in P4/ and M1/, which are the most varied maxillary teeth between skunk taxa. The mean length of P4/ in *B. obtusata* is only 7% greater than in *B. brevimala*, although the mean width is 22% greater. The lingual cusp of P4/ in *B. brevimala* also points more posteriorly than in *B. obtusata*, being nearer M1/ at its lingual tip rather than closer at its base or parallel as in *B. obtusata*. The M1/ of *B. obtusata* is 16% transversely wider on the average, but the labial anteroposterior length is 30% greater and the lingual anteroposterior length is 59% greater than in the *B. brevimala* type on the average.

TABLE 3. Skull measurements of *Brachyprotoma* specimens and mean skull measurements of *Brachyprotoma obtusata* and *Spilogale putorius*. Brigham Young University Vertebrate Paleontology (BYUVP) 7490 is from Crystal Ball Cave, Utah. American Museum of Natural History (AMNH) 12426 and 11772 are from Connard Fissure, Arkansas (Brown 1908, Hall 1936). U.S. National Museum (USNM) 8155 is from Cumberland Cave, Maryland (Gidley and Gazin 1938, Hall 1936). Carnegie Museum (CM) 11057A and 20233 are from Frankstown Cave, Pennsylvania (Hall 1936, Peterson 1926, P. M. Youngman 1984, pers. comm.). A skull misidentified as Carnegie Museum (CM) 308 (here listed as Cra. Pit) is from Crankshaft Pit, Missouri (Oesch 1967, Parmalee et al. 1969). Starred measurements are based on photos only. Measurements are in millimeters. The coefficients of variability (C.V.) have been multiplied by 100.

Location of measurement	BYUVP 7490	AMNH 12426	AMNH 11772	USNM 8155	CM 11057A	CM 20233	Cra. Pit	<i>B. obtusata</i> Mean	<i>B. obtusata</i> C.V.	<i>S. putorius</i> Mean	<i>S. putorius</i> C.V.
Width between orbits	17.1	18.0	—	18.2	—	17.0	—	17.7	3.63	17.0	7.52
Width between outer molars	19.8	20.5	—	20.1	—	19.6	—	20.1	2.25	19.3	6.62
Length of rostrum to internal nares	18.6	17.0*	18.0*	—	—	17.4	—	17.5	2.88	20.3	8.49
Length of cheek teeth series	11.2	11.0*	12.1	12.2	—	11.7	14.2*	12.2	9.75	14.2	6.80
P4/ anteroposterior length	5.7	5.9	6.2	6.2	6.4*	5.7	6.3*	6.1	4.32	6.0	8.80
P4/ greatest transverse width	3.3	3.8	3.9	3.9	4.0*	3.5	4.5*	3.9	8.30	3.7	9.97
M1/ labial anteroposterior length	3.0	3.8	4.1	4.0	3.8*	3.9	3.9*	3.9	2.98	4.8	7.96
M1/ lingual anteroposterior length	2.2	3.0	3.3	3.8	3.5*	3.5	3.6*	3.5	7.94	4.0	9.16
M1/ greatest transverse width	5.0	5.7	6.0	6.3	5.8*	5.3	5.7*	5.8	5.77	5.7	6.97

Since there is only minor variation in these characters among *B. obtusata* skulls (Table 3) but distinct difference between them and the Crystal Ball Cave specimen, and because the differences between the *B. brevimala* type and specimens of *B. obtusata* are far greater than would be expected within a species (based on the variation found among 73 individuals of *Spilogale putorius*, the most closely related extant species), erection of a new species for the Crystal Ball Cave specimen is clearly justified.

DISCUSSION.—*Brachyprotoma* specimens have been previously recovered from the following deposits of Early Pleistocene to Early Recent age: Port Kennedy Cave and Frankstown Cave, Pennsylvania (Cope 1899, Peterson 1926), Cumberland Cave, Maryland (Gidley and Gazin 1938), Crankshaft Cave and Brynjulfson Cave, Missouri (Oesch 1967, Parmalee and Oesch 1972, Parmalee et al. 1969), Connard Fissure, Arkansas (Brown 1908), and two sites in northern Yukon Territory, Canada (P. M. Youngman 1984, personal communication). Most of these specimens are lower jaws, and the only seven skulls (or skull fragments) that have been previously reported are Carnegie Museum 11057A and 20233, American Museum of Natural History 11772 and

12426, U.S. National Museum 8155 and 11960, and a specimen identified as Carnegie Museum 308 by Oesch (1967) but which does not correspond to that number in the Carnegie Museum catalogs (M. R. Dawson 1984, pers. comm.). Parmalee et al. (1969) illustrated this latter specimen but did not identify it by catalog number.

Cope (1899) named *Mephitis (Spilogale) obtusatus* for a single small dentary from Port Kennedy Cave, but E. D. Cope died before the completion of this paper, and a footnote stated that "none of the specimens labelled by Prof. Cope bear this name." Brown (1908) named the genus *Brachyprotoma*, and he considered *M. obtusatus* to belong to this genus as well as *M. fossidens* and *M. leptops*, two species named by Cope previous to the naming of *M. obtusatus*. From Connard Fissure Brown (1908) reported *B. fossidens*, *B. leptops*, and *B. obtusata* based on dentaries, and he named *B. pristina* based on two partial skulls and three dentaries (the skull cataloged as American Museum of Natural History 12426 is the type for the type species of this genus) and *B. spelaea* based on one dentary. The dentaries Brown (1908) identified as *B. fossidens* and *B. leptops* are far too large to belong to the same genus as the small speci-

mens he identified as *B. obtusata*, *B. pristina*, and *B. spelaea*, and no one since has considered these two species as belonging to the genus *Brachyprotoma*. Later Hay (1923) named *B. putoria* from Frankstown Cave.

The naming of multiple species of *Brachyprotoma* in the early publications listed above has been widely criticized by later workers because the amount of variation among specimens is less than that seen within living species. Hall (1936) and Kurten and Anderson (1980) considered the genus *Brachyprotoma* to be clearly monotypic, with the only valid species being *B. obtusata*, the earliest named species that can be applied to the genus. The *Brachyprotoma* skull from Crystal Ball Cave is the first specimen of *Brachyprotoma* distinct enough from *B. obtusata* to warrant the erection of an additional species of this genus.

Concerning the paleoecology of *Brachyprotoma*, Kurten and Anderson (1980) stated that this genus has always been associated with boreal faunas, although other skunk genera were also recognized at each site. This matches the "more boreal than present" nature of the Crystal Ball Cave assemblage and suggests that the post-Pleistocene climatic shift may have lead, directly or indirectly, to the extinction of *Brachyprotoma*. Since fossils of *Brachyprotoma* are only found in a few deposits and even then are few in number, this genus probably never had a high density of individuals in life.

The *Brachyprotoma brevimala* type was first misidentified as *Spilogale* (Heaton 1984), the most similar living genus. Miller (1982) reported cf. *Spilogale* from Crystal Ball Cave, possibly based on this same specimen. *Mephitis* was also mentioned in my preliminary report (Heaton 1984), but further examination proved that the anterior right dentary (BYUVP 7489) upon which the identification was based was equally referable to *Martes americana*, which is represented by additional material. Although both *Mephitis mephitis* and *Spilogale putorius* (*gracilis*) now inhabit the Snake Range (Hall 1981), and *Spilogale* has been recovered from deposits over 12,000 years old in Smith Creek Cave (Mead et al. 1982), their presence is unconfirmed in the Crystal Ball Cave assemblage.

Since *Brachyprotoma* seems to have lived

contemporaneously with other skunk genera, it is interesting to speculate about how their niches varied. All living skunks tend to be nocturnal and omnivorous, so they are rarely tied to specific foods or habitats. Minor niche differences do occur between living North American genera: *Spilogale* is the most carnivorous, *Mephitis* the most herbivorous, and *Conepatus* the most insectivorous. *Spilogale* has narrow sharp teeth, *Conepatus* at the other extreme has very broad teeth, and *Mephitis* is intermediate but has the longest tooth rows. *Brachyprotoma* (especially *B. brevimala*) has pushed the narrowing of the teeth seen in *Spilogale* to an extreme, converging on the carnivorous genus *Mustela*. This suggests that *Brachyprotoma* was more carnivorous than any of the living skunks.

Why *Brachyprotoma* lost P2/ and shortened its tooth rows, paralleling the genus *Conepatus*, is a mystery. Members of the genus *Mustela* have longer tooth rows than skunks, so in that respect *Brachyprotoma* diverged from *Mustela*. *Brachyprotoma* was trending in a direction that is difficult to explain. *Brachyprotoma* also did not survive the post-Pleistocene changes as did the aforementioned genera (although some species were lost and ranges altered). I propose that these two facts are correlated. *Brachyprotoma* was probably adapting to a specialized niche that existed during the Pleistocene but disappeared during the Recent. I also propose that this specialization was a feeding habit and/or preference for a particular prey item since the specializations discussed are all dental. No postcranial material has been reported to document additional specializations, and the most diagnostic skunk characters, scent glands and color patterns, are in the soft anatomy, which is obviously unavailable. With such limited data (about 27 specimens from nine sites), further speculation would be unwarranted. All that can be concluded is that *Brachyprotoma* was restricted to boreal conditions, was widespread in North America, was probably low in density, and did not survive the post-Pleistocene changes.

The evolution of the genus *Brachyprotoma* has been discussed by Kurten and Anderson (1980). They stated that it seems most closely related to *Spilogale*, but both were probably derived from the Mio-Pliocene genus

Promephitis. No intermediate forms are available to show the exact phylogeny, however. Some speculation can be made about the relationship of *B. brevimala* to *B. obtusata*. *Brachyprotoma brevimala* has gone to a greater extreme in the characters that differentiate *Brachyprotoma* from other skunks (shorter face and narrower teeth) and is therefore more specialized. Since specialists almost always evolve from generalists, *B. brevimala* probably evolved from *B. obtusata*. The fact that *B. obtusata* has been found in deposits from Early Pleistocene to Early Recent age (Kurten and Anderson 1980) and *B. brevimala* is known only from a Late Pleistocene to Recent deposit also supports this conclusion.

Family Felidae

Smilodon cf. *fatalis*

MATERIAL.—Partial left ectocuneiform (BYUVP 7530), claw (BYUVP 7497). Miller (1982) reported cf. *Smilodon* from Crystal Ball Cave based on a single vertebra (W. E. Miller 1983, pers. comm.), but this specimen is apparently lost (possibly due to an explosion that affected the collection).

DISCUSSION.—The ectocuneiform is dense, worn, and coated with a calcite crust. The claw is missing the outer plates but is otherwise in good condition. The specimens were compared with *Smilodon* and *Felis atrox*, the only two Late Pleistocene cats large enough to be considered, and both compare best with *Smilodon* (W. E. Miller 1984, pers. comm.). The ectocuneiform was previously referred to *Panthera atrox* (Heaton 1984), but comparison with actual specimens rather than casts shows that it is clearly *Smilodon*. The only previous citing of *Smilodon* in Utah is from the Silver Creek fauna of north central Utah (Miller 1976), but it has been found in Pleistocene assemblages throughout North America.

Kurten and Anderson (1980) considered *S. fatalis* to be the only valid species of Late Pleistocene *Smilodon* in North America, but it has been known by many other names. Based on this synonymy, the Crystal Ball Cave specimens are referred to *S. fatalis* although they are doubtfully identifiable to the species level.

Felis concolor

MATERIAL.—First right metacarpal (BYUVP 7502), 4 claws (BYUVP 7498–7501).

DISCUSSION.—*Felis concolor* is the only cat of its size presently living in North America, but similar-sized species of *Acinonyx* and *Homotherium* existed during the Pleistocene. *Lynx* and other species of *Felis* (disregarding those often placed in the genus *Panthera*) are distinctly smaller than *F. concolor*, and *Smilodon*, *Panthera atrox*, and *P. onca* are distinctly larger. The Crystal Ball Cave specimens were compared with material of *Felis* species, *Acinonyx*, and *Homotherium* at the Los Angeles County Museum and found to match perfectly in size and shape with specimens of *F. concolor*; but they clearly differ from the other felids mentioned. *Felis concolor* presently lives throughout the Snake Range (Hall 1981), and J. C. Bates (1983, pers. comm.) reported a citing in the Snake Valley near Gandy as well as many higher in the mountains.

Lynx cf. *rufus*

MATERIAL.—Right C1/ (BYUVP 7494), right P/4 (BYUVP 7496). The anterior portion of a right maxilla without teeth (BYUVP 7495) is probably also referable to *Lynx*.

DISCUSSION.—*Lynx rufus* currently inhabits the area of Crystal Ball Cave (J. C. Bates 1983, pers. comm.), but *L. canadensis* ranges only as close as central Utah and northward and prefers colder climates (Hall 1981). *Lynx canadensis* is slightly larger than *L. rufus* and has considerably larger feet (Ingles 1965). The specimens recovered fall in the size range of both *L. rufus* and *L. canadensis*, but they tend to be closer in size to *L. rufus*. None of the claws recovered could be referred to this genus, so the difference in foot size was not helpful. Since *L. rufus* presently lives around the cave, the specimens are referred to it.

Order Perissodactyla

Family Equidae

Equus cf. *scotti*

MATERIAL.—Left cuneiform (BYUVP 7542), right lunar (BYUVP 7544), 2 right scaphoids (BYUVP 7549, 7550), right magnum (BYUVP 7561), second phalanx (LACM

TABLE 4. Measurements of *Equus* first phalanges from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	Maximum proximo-distal length	Maximum proximal width		Minimum medial width		Maximum distal width	
		Transverse	Antero-posterior	Transverse	Antero-posterior	Transverse	Antero-posterior
BYUVP 7580	76.8	38.1	28.6	27.0	17.7	35.8	20.8
BYUVP 7581	72.0	38.3	30.6	24.2	16.8	33.2	20.0
BYUVP 7582	—	—	—	—	16.4	—	16.1
BYUVP 7583	75.8	38.6	30.3	24.8	17.4	33.9	19.5
LACM 123681	74.9	39.7	31.5	27.0	18.0	37.5	21.7
LACM 123682	74.1	—	31.8	25.4	17.6	34.4	20.4

TABLE 5. Measurements of *Equus* second phalanges from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	Maximum proximo-distal length	Maximum proximal width		Minimum medial width		Maximum distal width	
		Transverse	Antero-posterior	Transverse	Antero-posterior	Transverse	Antero-posterior
BYUVP 7587	—	—	27.7	—	—	—	—
BYUVP 7588	47.5	48.7	31.7	42.3	21.7	46.5	25.6
BYUVP 7589	44.2	41.5	28.1	33.2	19.4	35.5+	23.9
BYUVP 7590	—	—	25.4	—	—	—	—
BYUVP 7591	39.3+	—	27.0+	—	21.2+	—	25.5
BYUVP 7593	37.0	39.1	22.8	30.4	—	31.1+	17.1
BYUVP 7594	36.5	31.9	24.0	28.2	15.6	30.4	19.2
LACM 123683	51.8	62.0	35.2	52.7	24.1	57.1	28.8
LACM 123684	45.2	44.0+	30.8	37.2	21.2	37.1	24.5
LACM 123685	40.6	42.1	26.7	36.7	19.5	39.1	25.0

TABLE 6. Measurements of *Equus* third phalanges from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	Anterior height	Maximum transverse width	Maximum antero-posterior width	Articulation surface	
				Transverse	Antero-posterior
BYUVP 7595	40.6	61.7	44.2	49.2	22.4
BYUVP 7596	39.4+	—	—	—	—
BYUVP 7597	32.7	39.6	38.0+	36.0	13.8
BYUVP 7600	47.0+	48.7	49.1+	37.8	14.8
BYUVP 7601	34.0	37.1	34.6+	34.0	16.6
BYUVP 7602	—	—	—	34.4	14.0
BYUVP 7603	—	—	—	41.0	13.6
BYUVP 7605	35.2	41.1	38.0	37.3	13.6
BYUVP 7606	37.7	—	—	33.7	14.1
BYUVP 7607	40.8	—	—	29.2	15.3
BYUVP 7608	39.0	—	—	40.7	13.8
BYUVP 7610	—	33.2	27.8+	—	—

123683), third phalanx (BYUVP 7595). A juvenile left P/2 (BYUVP 7623), a partial juvenile first phalanx (BYUVP 7586), a second phalanx (BYUVP 7588), 3 partial third phalanges (BYUVP 7596, 7607, 7608), and a distal sesamoid (BYUVP 7622) probably belong to this species also. Phalanx measurements are listed in Tables 4, 5, and 6.

DISCUSSION.—Several species of large horses have been recognized from the Late

Pleistocene of western North America. The Rancho La Brea asphalt deposits have yielded a single species of large horse (Savage 1951) usually referred to *E. occidentalis* (Merriam 1913, Stock 1963, Willoughby 1974), although the validity of this name has been questioned (Miller 1971). Based on comparative material and measurements made by Willoughby (1974), the large Crystal Ball Cave horse is distinct from the Rancho La Brea horse in

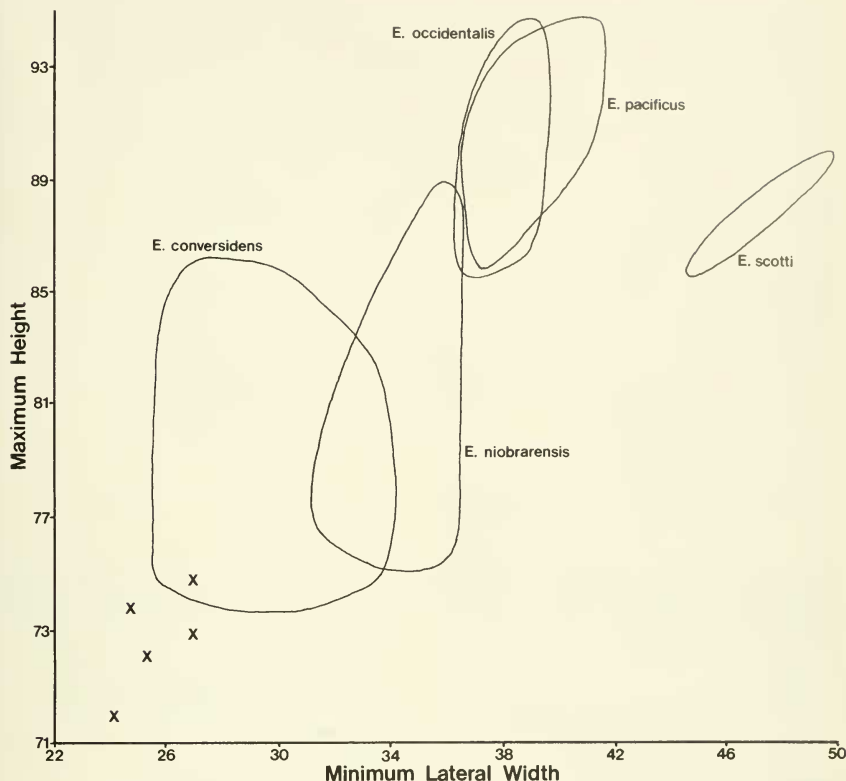


Fig. 6. Plot of *Equus* first phalanges from Crystal Ball Cave (X's) and ranges of variation for some Late Pleistocene North American species (circumscribed). The number of specimens plotted to show the range of variation were 46 of *E. conversidens*, 9 of *E. niobrarensis*, 6 of *E. occidentalis*, 6 of *E. pacificus*, and 2 of *E. scotti*. These measurements were taken from Dalquest and Hughes (1965), Gazin (1936), A. H. Harris (1984, pers. comm.), and Harris and Porter (1980). Measurements are in millimeters.

having more transversely broad phalanges (Figs. 6, 7, and 8) and carpals with relatively larger articulation surfaces. The Crystal Ball Cave specimens are distinctly larger than *E. niobrarensis* based on measurements given me by A. H. Harris (1983, pers. comm.) and in Harris and Porter (1980). Harris (1983, pers. comm.) also provided me with measurements of *E. pacificus* (although the validity of this species has been questioned by Savage 1951) from Fossil Lake, Oregon, and phalanges of this species match well in size with the large Crystal Ball Cave horse but are not as transversely broad.

Gazin (1936) listed measurements of the type specimen of *E. scotti*, and, of all specimens and data seen, only it has phalanges that are as transversely broad as the Crystal Ball Cave specimens. The second phalanx (LACM 123683) is slightly larger than the *E. scotti* type but has identical proportions (Fig. 7), and the third phalanx (BYUVP 7595), although smaller because it is of a subadult, has the same proportions as the anterior third phalanges of the *E. scotti* type (Fig. 8). Dalquest (1964) stated that *E. scotti* was very heavily built, and this would suggest that the foot and toe bones are broad compared with

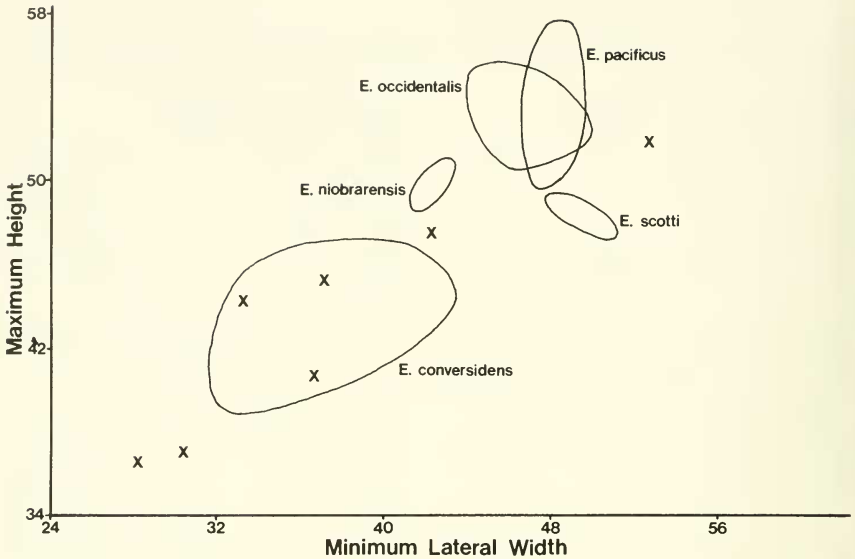


Fig. 7. Plot of *Equus* second phalanges from Crystal Ball Cave (X's) and ranges of variation for some Late Pleistocene North American species (circumscribed). The number of specimens plotted to show the range of variation were 26 of *E. conversidens*, 3 of *E. niobrarensis*, 8 of *E. occidentalis*, 4 of *E. pacificus*, and 2 of *E. scotti*. These measurements were taken from Dalquest and Hughes (1965), Gazin (1936), A. H. Harris (1984, pers. comm.), and Harris and Porter (1980). Measurements are in millimeters.

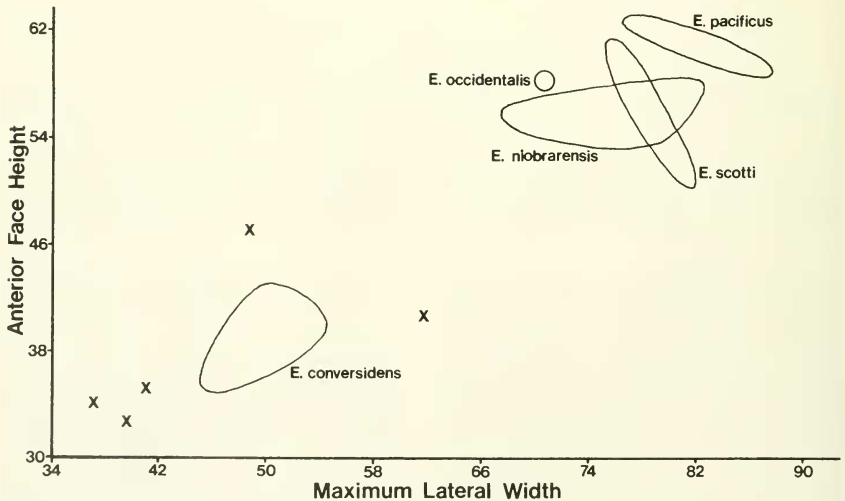


Fig. 8. Plot of *Equus* third phalanges from Crystal Ball Cave (X's) and ranges of variation for some Late Pleistocene North American species (circumscribed). The number of specimens plotted to show the range of variation were 6 of *E. conversidens*, 5 of *E. niobrarensis*, 1 of *E. occidentalis*, 2 of *E. pacificus*, and 2 of *E. scotti*. These measurements were taken from Dalquest and Hughes (1965), Gazin (1936), A. H. Harris (1984, pers. comm.), and Harris and Porter (1980). Measurements are in millimeters.

other species of *Equus*. The large carpals from Crystal Ball Cave mentioned above, especially the cuneiform and magnum, are broad and have much larger articulation surfaces than the Rancho La Brea horse. Based on this limited information in the literature, the largest carpals listed above compare most favorably with *E. scotti* also.

Equus scotti was originally named and described from Texas by Gidley (1900), and most specimens have been found in that state (Dalquest 1964, Gidley 1903, Johnston 1937). Hopkins et al. (1969) recovered a left metatarsal from the Late Pleistocene American Falls Lake Beds of southeastern Idaho that they referred to *E. scotti*. It is therefore not unlikely that *E. scotti* lived in Utah. A large horse was represented at Smith Creek Cave by a single vestigial metapodial (Miller 1979), but no attempt was made to identify it to species.

BYUVP 7588 is not as laterally broad as LACM 123683 but is too large to belong with the smaller species. The epiphysis is not fully fused, showing that it represents a subadult. It is the only bone from Crystal Ball Cave that matches well with the Rancho La Brea horse, although it is slightly smaller. But, since it may differ by only individual, foot, or age variation from the better represented *E. cf. scotti*, it is tentatively referred to that species.

Equus ? conversidens

MATERIAL.—Right M3/ (LACM 123677), thoracic vertebra (BYUVP 7687), 3 right pisiforms (BYUVP 7536–7538), left pisiform (BYUVP 7539), 2 right cuneiforms (BYUVP 7540, 7541), 4 right lunars (BYUVP 7543, 7545–7547), partial left lunar (BYUVP 7548), 4 right scaphoids (BYUVP 7551–7554), 4 partial left scaphoids (BYUVP 7555–7558), 2 right trapezium-trapezoids (BYUVP 7559, 7560), 2 right magnums (BYUVP 7562, 7563), partial right magnum (BYUVP 7564), left magnum (LACM 123678), 2 partial right unciforms (BYUVP 7565, 7566), proximal tibia epiphysis (BYUVP 7570), distal epiphysis of right tibia (BYUVP 7571), partial distal epiphysis of left tibia (BYUVP 7572), right calcaneum (LACM 123679), left calcaneum (BYUVP 7573), right astragalus (BYUVP 7575), right juvenile astragalus (BYUVP 7574), left astragalus

(LACM 123680), right navicular (BYUVP 7576), left navicular (BYUVP 7577), left cuboid (BYUVP 7579), right meso-cubo (BYUVP 7578), proximal portion of left metatarsal (BYUVP 7567), 2 distal metapodial epiphyses (BYUVP 7565, 7569), 6 first phalanges (BYUVP 7580, 7581, 7583, LACM 123684, 123685), 3 partial first phalanges (BYUVP 7582, 7584, 7585), 5 second phalanges (BYUVP 7589, 7593, 7594, LACM 123684, 123685), 4 partial second phalanges (BYUVP 7587, 7590–7592), 5 third phalanges (BYUVP 7597, 7600, 7601, 7605, 7606), 2 partial third phalanges (BYUVP 7602, 7603), juvenile third phalanx (BYUVP 7610), 11 proximal sesamoids (BYUVP 7611–7621). Phalanx measurements are listed in Tables 4, 5, and 6.

DISCUSSION.—In addition to the fossils of large horses from Crystal Ball Cave (referred to *E. cf. scotti*) are numerous bones of smaller horses. Some of these compare well with *E. conversidens*, the species to which most small Pleistocene North American horse fossils have been assigned, but others do not. Considerable time has been spent evaluating the size and morphologic variation among these bones and comparing the results with descriptions and measurements in the literature. But both complexities within this collection and disagreements regarding valid species in the literature have prevented positive species identification of these small horse bones.

Equus conversidens (Owen 1869) has been considered by some workers to be the only valid species of small Pleistocene horse in North America (Harris and Porter 1980, Miller 1971), and most other named species of small Pleistocene horses have at some time been synonymized with this species (Dalquest and Hughes 1965, Hibbard 1955, Hibbard and Taylor 1960). However, most workers presently recognize at least two species. Owen (1869) named *E. tau* at the same time he named *E. conversidens*. Poor illustrations of the type specimens have caused some workers to consider *E. conversidens* and *E. tau* synonymous (Hibbard 1955). But Dalquest (1979) and Mooser and Dalquest (1975), after researching the early descriptions (the type specimen of *E. tau* is lost), considered these two species distinct. The teeth that Mooser and Dalquest (1975) assigned to *E. tau* are smaller than those of *E.*

conversidens, and the metapodials are longer and more slender. Skinner (1942) assigned a first phalanx from Papago Springs Cave, Arizona, to *E. tau* because it was much narrower than those of *E. conversidens* from the same assemblage. But, based on his measurements, this phalanx is narrower transversely than anteroposteriorly, making it doubtful of being horse at all.

Hay (1915) named *E. francisci*, which was synonymized with *E. conversidens* by Hibbard and Taylor (1960). But Lundelius and Stevens (1970) reprepared the metatarsal of the type specimen and found it to be distinctly longer and narrower than that of *E. conversidens*. Lundelius and Stevens (1970) therefore considered *E. francisci* a valid species, and they synonymized *E. quinni* (based on the similar long metatarsal) and *Onager zoyatalis* (based on dental similarities) to it. Dalquest (1979) considered *E. francisci*, as well as *E. littoralis*, *E. achates*, and *E. quinni*, to be synonymous with *E. tau*, and he considered *E. conversidens* and *E. tau* the only two valid species of small Pleistocene North American horses.

Based on an illustration in Lundelius and Stephens (1970), the M3/ of *E. francisci* is distinctly wider transversely than that of *E. conversidens*, although they are of similar anteroposterior length. LACM 123677, although quite worn, has the same width and length as the *E. francisci* type and has an enamel pattern most similar to it also. Dalquest (1979) synonymized *E. francisci* with *E. tau*, but the M3/ of the lectotype of *E. tau* illustrated by Mooser and Dalquest (1975) is not transversely broad like the *E. francisci* type and Crystal Ball Cave M3/. Unfortunately the only phalanx measurements given in the literature are for *E. conversidens*, except the questionable first phalanx assigned to *E. tau* by Skinner (1942).

The only phalanges from Crystal Ball Cave that compare well with measurements of *E. conversidens* phalanges in the literature are three of the five second phalanges (Fig. 7). The other two second phalanges (BYUVP 7593, 7594) are distinctly smaller than any assigned to *E. conversidens* yet have complete epiphyseal fusion. All nine first phalanges are from individuals intermediate in size between those represented by the two

sets of second phalanges, and all are small compared with the first phalanges assigned to *E. conversidens* in the literature (Fig. 6). Six of the eleven third phalanges articulate well with the three larger second phalanges yet are smaller than the third phalanges assigned to *E. conversidens* in the literature (Fig. 8). The other third phalanx (BYUVP 7600) is larger than any assigned to *E. conversidens* and too large to articulate with any of the second phalanges under discussion.

It is important to consider sexual dimorphism, individual variation, and variation among different feet of the same individual to see how much variation is expected within a species. Willoughby (1974), in a table of bone measurements from 25 species and races of *Equus*, listed mean dimensions for both sexes with respect to two characters: metacarpal midwidth and metacarpal midwidth divided by length. Metacarpals of males had a midwidth of 3.1% to 7.3% greater than females and a midwidth divided by length of 2.3% to 6.9% greater than females. Species with more sexual dimorphism in metacarpal width tended to also have more dimorphism in width relative to length, so male metacarpals tend to be more robust and just slightly longer than female metacarpals. These measurements show that sexual dimorphism is not great in *Equus* and certainly not sufficient to have caused the variability seen among the small Crystal Ball Cave equids.

Howe (1970), in a study of *Equus (Plesipus) simplicidens*, showed that individual variation in bone size can be greater than previously thought. Because the large number of specimens at Nebraska's Broadwater Quarry fell into a single size curve with no gaps, he concluded that they all represent a single species, and he synonymized a number of species that had previously been named based on limited material at other sites. Table 5 of Howe (1970) shows that the largest metacarpal and metatarsal lengths and widths average 32% larger than the smallest corresponding measurements, and none are more than 36% larger. Even with a sample size of 97 to 190, the metapodials measured by Howe (1970) show less variation than do the few second and third phalanges from Crystal Ball Cave.

TABLE 7. Measurements of first phalanges of *Camelops cf. hesternus* (C) and *Hemiauchenia cf. macrocephala* (H) from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	ID	Maximum proximo-distal length	Maximum proximal width		Minimum medial width		Maximum distal width	
			Transverse	Antero-posterior	Transverse	Antero-posterior	Transverse	Antero-posterior
BYUVP 7627	C	117	39+	35+	20	18	33+	28
LACM 123689	C	114	43	35	22	19	35	29
LACM 123691	C	—	32	32	17	18	—	—
BYUVP 7640	H	—	23	19	—	—	—	—
LACM 123690	H	100	28	32	15	14	22	18

Isolated front and rear phalanges are usually indistinguishable and therefore have an additional degree of variation. Front and rear phalanx measurements were taken from recent *E. caballus* and *E. burchelli* specimens, and the larger measurements for each species averaged 4.2% larger than the smallest corresponding measurements with a maximum of 9.4% larger. But even this much variability, in addition to sexual and individual variation, does not adequately account for the great size range among the small Crystal Ball Cave equids.

Six measurements of the 5 second phalanges from Crystal Ball Cave (excluding those referred to *E. scotti*) show that the largest measurements are 24% to 43% larger than the smallest corresponding measurements with an average of 31.5% larger. Eleven measurements of the 9 third phalanges from Crystal Ball Cave show that the largest measurements are 7% to 122% larger than the smallest corresponding measurements with an average of 50.7% larger. Considering the second and third phalanges separately, each has enough variation to make it marginal whether they could all be assigned to the same species considering sexual, individual, and foot variation. The variation seems even more extreme when one considers that the smallest second phalanges (BYUVP 7593, 7594) are from much smaller individuals than the smallest third phalanx, and the largest third phalanx (BYUVP 7600) is from a larger individual than the largest second phalanx. This is far more variation than can be accounted for by the sexual, individual, and foot variation for a single species as discussed above, and it suggests that multiple species of horse smaller than *E. cf. scotti* are represented at Crystal Ball Cave.

Finding a dividing line between two species in this material is nearly impossible, however. Most of the material could be assigned to a species of horse 15% smaller than the smallest material assigned to *E. conversidens*, but the two smallest second phalanges (BYUVP 7593, 7594) and the largest third phalanx (BYUVP 7600) seem too far from the mean to belong to this supposed species. Until more phalanx measurements are available for small Pleistocene horses other than *E. conversidens*, it is difficult to determine how many species are represented by the smaller *Equus* fossils from Crystal Ball Cave and whether most of the material represents an unusually small variety of *E. conversidens*, a species distinct from *E. conversidens* such as *E. tau* and/or *E. francisci*, or both.

Order Artiodactyla
Family Camelidae
Camelops cf. hesternus

MATERIAL.—Right scaphoid (LACM 123686), left scaphoid (LACM 123687), left lunar (BYUVP 7624), left magnum (BYUVP 7625), right unciform (BYUVP 7626), distal fragment of metapodial (BYUVP 7629), 2 first phalanges (BYUVP 7627, LACM 123689), proximal portion of first phalanx without epiphysis (LACM 123691), partial proximal epiphysis of first phalanx (BYUVP 7638), 3 second phalanges (LACM 123692, BYUVP 7630, 7632), 3 proximal portions of second phalanges (BYUVP 7633, 7634, 7637), 3 partial proximal portions of second phalanges (BYUVP 7628, 7635, 7636), 3 third phalanges (BYUVP 7639, 7641, 7642). Six sesamoids (BYUVP 7644–7649) are probably of *Camelops* but may represent *Bison*. Phalanx measurements are listed in Tables 7, 8, and 9.

TABLE 8. Measurements of second phalanges of *Camelops* cf. *hesternus* (C) and *Hemiauchenia* cf. *macrocephala* (H) from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	ID	Maximum proximo-distal length	Maximum proximal width		Minimum medial width		Maximum distal width	
			Transverse	Antero-posterior	Transverse	Antero-posterior	Transverse	Antero-posterior
BYUVP 7630	C	70+	35	29	24	17	30+	22
BYUVP 7632	C	67+	37	31	29	19	—	—
BYUVP 7633	C	—	31+	31	27	20	—	—
BYUVP 7634	C	—	34+	28+	—	—	—	—
BYUVP 7635	C	—	—	31	—	—	—	—
BYUVP 7636	C	—	—	26+	—	—	—	—
BYUVP 7637	C	—	34+	30	—	19	—	—
LACM 123692	C	69	37	31	26	19	35	23
BYUVP 7631	H	52	28	23	20	14	23	20

TABLE 9. Measurements of third phalanges of *Camelops* cf. *hesternus* from Crystal Ball Cave. All measurements are in millimeters and parallel to the main bone axes.

Catalog number	Maximum proximo-distal length	Maximum proximal width	
		Transverse	Antero-posterior
BYUVP 7639	23+	22	21
BYUVP 7641	29+	23	22
BYUVP 7642	33+	25	23

DISCUSSION.—Webb (1965, 1974) recognized only four valid genera of Late Pleistocene North American camels: *Titanotylopus*, *Camelops*, *Hemiauchenia* (= *Tanupolama*), and *Paleolama* (in order of decreasing size). *Titanotylopus* is somewhat common and *Camelops* is very common in Late Pleistocene assemblages of western North America, but neither has been found in the east (Webb 1974). *Hemiauchenia* is found in Late Pleistocene deposits throughout the Americas (Webb 1974) and is commonly associated with *Camelops* (Miller 1979). *Paleolama* has only been found in Florida, Texas, and southern California in Pleistocene deposits of North America (Miller 1976). Miller (1982) identified *Camelops* and *Hemiauchenia* from Crystal Ball Cave.

The specimens listed above fall within the range of variation of *Camelops hesternus* measurements from Rancho La Brea, southern California (Webb 1965) and Selby and Dutton, eastern Colorado (Graham 1981). T. E. Downs (1984 pers. comm.) provided me with 8 first phalanx measurements of *Titanotylopus* sp., 21 of *Camelops hesternus*, and 21 of *Hemiauchenia* sp. from southern California deposits. Those of *Titanotylopus* range from 105 to 138 mm in length with an average of 121 mm, those of *Camelops hesternus* range from

105 to 125 mm in length with an average of 116 mm, and those of *Hemiauchenia* range from 91 to 110 mm in length with an average of 94 mm. The two complete first phalanges from Crystal Ball Cave, both of which are of adults based on epiphyseal fusion and bone density, measure 114 and 117 mm in length (Table 7). Although there is some overlap in first phalanx length between these genera, the Crystal Ball Cave specimens clearly match best with *Camelops*.

Savage (1951) recognized four valid species of *Camelops*: *C. hesternus* and *C. huerfaniensis*, which are larger, and *C. sulcatus* and *C. minidokae*, which are smaller; and Webb (1965), in his detailed description of *Camelops*, supported this system. Based on limb bone measurements given by Savage (1951), *C. minidokae* was about 14% smaller than *C. hesternus*. *Camelops huerfaniensis* can only be distinguished from *C. hesternus* and *C. sulcatus* can only be distinguished from *C. minidokae* based on dental characters (Graham 1981, Savage 1951). Both *C. minidokae* and *C. sulcatus* are too small to match the Crystal Ball Cave specimens, and both are known only from pre-Wisconsinan deposits (Kurten and Anderson 1980).

Camelops hesternus and *C. huerfaniensis* are very similar and may be conspecific (Hop-

kins 1955, Savage 1951). Both are known from the Late Pleistocene, and both are known from Idaho (Gazin 1935, Hopkins 1955, Hopkins et al. 1969) and Colorado (Cragin 1892, Graham 1981). *Camelops hesternus* is the only species of *Camelops* reported from Utah. A *Camelops hesternus* skull was recovered from a lava tube 140 km (87 miles) east-southeast of Crystal Ball Cave (Romer 1928, 1929) and dated at $11,075 \pm 225$ Y.B.P. (Nelson and Madsen 1979). *Camelops* cf. *hesternus* was reported from the Silver Creek fauna in north central Utah (Miller 1976). *Camelops* sp. was reported from Smith Creek Cave (Harrington 1934, Stock 1936, Miller 1979), but the only material mentioned is a right navicular (Miller 1979), and no attempt was made to identify it to species.

Since the Crystal Ball Cave specimens match measurements of *C. hesternus* by T. E. Downs (1984, pers. comm.), Graham (1981), and Webb (1965), and since *C. hesternus* is the only species reported from the state of Utah, the Crystal Ball Cave specimens are referred to this species. But, since the only diagnostic character to distinguish *C. hesternus* from *C. huerfanensis* is a dental feature not applicable to the Crystal Ball Cave specimens (Hopkins 1955, Savage 1951), *C. huerfanensis* cannot be positively eliminated on the basis of these foot elements.

Hemiauchenia cf. *macrocephala*

MATERIAL.—Distal right portion of metapodial (LACM 123688), first phalanx (LACM 123690), partial proximal portion of first phalanx (BYUVP 7640), second phalanx (BYUVP 7631). Phalanx measurements are listed in Tables 7, 8, and 9.

DISCUSSION.—Two genera of small camels are recognized from the Pleistocene of North America: *Hemiauchenia* and *Paleolama* (Webb 1974). Based on illustrations of *Hemiauchenia* (= *Tanupolama*) *macrocephala* (= *stevensi*) by Stock (1928), and *Paleolama mirifica* by Webb (1974), the metapodials of *H. macrocephala* are 63% longer but 3% transversely narrower at the distal end than those of *P. mirifica*. The Crystal Ball Cave metapodial fragment is 12% transversely narrower than the *H. macrocephala* specimens illustrated by Stock (1928) and measurements

from the Vallecito Creek site in southern California and Ringold site in Washington State provided by T. E. Downs (1984, pers. comm.). The first phalanges from Crystal Ball Cave fall well within the range of *Hemiauchenia* specimens reported by T. E. Downs (1984, pers. comm.), McGuire (1980), and Schultz (1937). Nothing was available to compare the second phalanx with, but it is from the same size of camel as the other elements. The Crystal Ball Cave specimens clearly match the more narrow-legged *Hemiauchenia* rather than the more broad-legged *Paleolama*.

Webb (1974) synonymized the North American genus *Tanupolama* with the South American genus *Hemiauchenia* and recognized six valid species. Of these, only *H. macrocephala* is found in the late Pleistocene of North America. *Hemiauchenia macrocephala* represents the synonymy of a number of previously named North American species (Webb 1974), and it is the best-known Pleistocene llama (Kurten and Anderson 1980). Since only this species matches the age and locality of the Crystal Ball Cave assemblage, and since the Crystal Ball Cave specimens match specimens from other sites assigned to this species, the four Crystal Ball Cave specimens are referred to *H. macrocephala*. Characters separating this species from others of *Hemiauchenia* are almost entirely dental (Webb 1974), however, and are therefore not applicable to the Crystal Ball Cave material.

Miller (1982) reported *Hemiauchenia* from Crystal Ball Cave based on the same material reported here. Miller (1979) reported ? *Hemiauchenia* sp. from Smith Creek Cave based on a left cuboid, the proximal portion of a scapula, and a juvenile metapodial. *Hemiauchenia* is better represented than *Camelops* at Smith Creek Cave by a ratio of 3 to 1, but *Camelops* is better represented than *Hemiauchenia* at Crystal Ball Cave by a ratio of 7 to 1. This difference seems even more dramatic in light of the selection for smaller bones at Crystal Ball Cave but not at Smith Creek Cave. Although this difference could be explained by slight age differences in these faunas, human intervention, or chance preservation, I feel it is more likely due to habitat differences between these two genera of camels.

Kurten and Anderson (1980) stated that "... *Hemiauchenia* had a long stride and was highly cursorial. It was a plains-dweller and probably fed primarily on grass." About *Camelops* they stated: "Although primarily a grazer, *Camelops*, with its long neck and legs, was probably an occasional browser." Although these two camels are thought to have been plains-dwelling grazers, it is interesting to speculate about their habitat differences. Webb (1974) presented strong evidence that *Hemiauchenia* gave rise to the mountain-dwelling South American llamas. *Camelops*, on the other hand, probably resembled the living dromedary camel (Kurten and Anderson 1980), which prefers flat plains habitats. The fact that *Camelops* is by far the better represented camel at Crystal Ball Cave, located in a small outlier surrounded by a flat valley, and *Hemiauchenia* is better represented at nearby Smith Creek Cave, located in a canyon at the base of a high mountain, suggests that *Hemiauchenia* preferred higher elevations and/or more rugged terrain than *Camelops*.

Family Cervidae cf. *Cervus elaphus*

MATERIAL.— First phalanx (BYUVP 7811).

DISCUSSION.— Several cervid phalanges from Crystal Ball Cave are intermediate in size between *Cervus* and *Odocoileus*. BYUVP 7811 (60.2 mm long) is the largest of these and is much closer in size to *Cervus*. In comparison with the others it is distinctly larger and more robust, yet high bone porosity suggests that it is of a subadult. *Navahoceros fricki* is another Late Pleistocene cervid found as close to Utah as Arizona and Wyoming, and its size is intermediate between *Odocoileus* and *Cervus* (Kurten and Anderson 1980). No character has been described to differentiate phalanges of *Navahoceros* and *Cervus*, and no comparative material of *Navahoceros* was available to the author. *Cervus elaphus* was recovered from Smith Creek Cave (Miller 1979) and has been reported living in the Snake Range in Recent times (Hall 1981), so the phalanx is referred to this species.

Odocoileus hemionus

MATERIAL.— Partial right dentary with P/3/4, M/1 (BYUVP 7651) and anterior left

dentary with P/3/4, M/1/2 (BYUVP 7650, probably from the same individual), partial right dentary with P/3 (BYUVP 7652), left patella (BYUVP 7934). Of 21 first and 51 second phalanges of noncamelid artiodactyls, most compare best in size and proportions with *Odocoileus*.

DISCUSSION.— BYUVP 7650 and 7651 are of a juvenile and compare best in size and degree of hypsodonty with juvenile individuals of *O. hemionus*. The P/4's in these dentaries have three lobes rather than two, a condition seen in juveniles of *Odocoileus* but not *Antilocapra*. The P/3 of BYUVP 7652 is identical to adult *O. hemionus* and distinctly larger and less hypsodont than *A. americana*. The first and second phalanges from Crystal Ball Cave that compare best with *Odocoileus* have a slightly larger mean size than those of Recent *O. hemionus* living in Utah. This demonstrates that the Crystal Ball Cave specimens are of *O. hemionus* rather than the smaller *O. virginiana* (Hall 1981), and it suggests that deer decreased in size at the end of the Pleistocene much as did *Ovis canadensis* (Harris and Mundel 1974).

Based on numbers of phalanges, *Odocoileus* is the best represented artiodactyl in the Crystal Ball Cave assemblage; but *Antilocapra americana* is now the dominant artiodactyl of the local fauna. *Odocoileus* sp. was reported at Smith Creek Cave by Goodrich (1965), but no material was found by Miller (1979). Mule deer now live in Smith Creek Canyon (Miller 1979) and sometimes come down to Gandy at night to feed in cultivated fields (J. C. Bates 1984, pers. comm.). The replacement of *Odocoileus* by *Antilocapra*, suggested by comparison of the Crystal Ball Cave assemblage with the living community, shows that plant communities preferred by deer apparently moved upward in altitude from Snake Valley to higher elevations in the Snake Range at the close of the Pleistocene.

Family Bovidae *Antilocapra americana*

MATERIAL.— Partial left maxilla with M1/2, 3/ (BYUVP 7656).

DISCUSSION.— The M3/ was distinguished from *Odocoileus* by being very hypsodont, transversely narrower, and having a more

pointed posterior end as in *Antilocapra*. It is identical in size and proportions to the largest male specimen of *A. americana* available for comparison and distinctly larger than the extinct Pleistocene antilocaprids.

Since *A. americana* presently lives around Gandy Mountain in small herds, it is not surprising to find it in the assemblage. But it is not well represented as a fossil, suggesting that Snake Valley has not always been the treeless desert that it is now. Since *Odocoileus hemionus* is the dominant artiodactyl in the fossil assemblage and *Antilocapra americana* is the dominant living artiodactyl in the area, *Antilocapra americana* must have become abundant in the area in Recent times and replaced *Odocoileus hemionus*, probably due to changes in the vegetation.

Ovis canadensis

MATERIAL.—Posterior portion of right dentary with M1/2, 2/3 (LACM 123695) and posterior portion of left dentary with M/3 (LACM 123696, probably from the same individual), left magnum (BYUVP 7780).

DISCUSSION.—The molars of LACM 123695 and 123696 are distinctly larger and more robust than living *Ovis aries* and are even slightly larger than Recent *O. canadensis*. This suggests that the jaws are Pleistocene rather than Recent in age because Harris and Mundel (1974) demonstrated that *O. canadensis* became reduced in size at the end of the Pleistocene.

Bighorn sheep are commonly found in Pleistocene assemblages in the Great Basin (Hibbard and Wright 1956, Stokes and Condie 1961). Even in historic times they have been reported natively in the Snake Range (Durrant 1952, Hall 1946, 1981). *Ovis canadensis* was temporarily lost from the Snake Range but was reintroduced in the middle 1900s and presently thrives in the higher elevations (Mead et al. 1982). Shortly after this reintroduction, one young ram lived on Gandy Mountain for several months (J. C. Bates, 1983, pers. comm.), but this is the only citing known to me for such a low elevation in the area.

Ovis canadensis is the best represented ungulate in the Smith Creek Cave assemblage, and *Oreamnos harringtoni* is also well repre-

sented (Miller 1979). No *Oreamnos* material has been identified from Crystal Ball Cave, and *Ovis* is less represented than horse, camel, and deer. This difference between the two assemblages is probably because wild goats and sheep are mountainous animals and would rarely venture into Snake Valley. It may also represent the fact that Smith Creek Cave was a shelter for humans since many *Ovis* fossils found there appear butchered (Miller 1979).

Ovis cf. aries

MATERIAL.—Right metacarpal and 2 first phalanges found associated (BYUVP 8300).

DISCUSSION.—These associated bones were found as float near the east entrance of Crystal Ball Cave, and their greasy appearance suggests that they are Recent. The length and shape of the metapodial demonstrates that it is of the genus *Ovis*, and it is slightly longer than the *O. aries* specimens to which it was compared but distinctly smaller than living *O. canadensis*. *Ovis aries* is now a common domestic animal in the area, and many roam on Gandy Mountain each winter (J. C. Bates 1984, pers. comm.).

Since this species is a Recent introduction from Europe, its presence has little significance to this study. It does show, however, that the smaller bones of large mammals are still being deposited in Crystal Ball Cave, probably by woodrats since gates on the cave entrances would keep out all but the smallest carnivores. These specimens were found just north of the east entrance, an area where woodrats and their nests are often found.

cf. Symbos cavifrons

MATERIAL.—Second phalanx (BYUVP 7923), distal portion of second phalanx (BYUVP 7924), 2 partial second phalanges (BYUVP 7925, 7926), 2 distal portions of second phalanges (BYUVP 7921, 7922).

DISCUSSION.—These short, broad second phalanges compare best among living species to *Ovibos moschatus* but are slightly longer and narrower. BYUVP 7923 is the most complete specimen, missing only one side of the distal extension. It has a length of 42 mm, a proximal transverse width of 27 mm, and a

proximal anteroposterior width of 26 mm. BYUVP 7924 has the same proximal measurements as BYUVP 7923, and BYUVP 7925 has a proximal anteroposterior width of at least 26 mm. The distal ends taper in such a way that they are hard to measure. The general shape of these second phalanges shows that they are from an animal more closely related to *Ovibos* than any other living bovid. Few phalanx measurements of Pleistocene oxen are available, but Nelson and Madsen (1980) and Stokes and Hansen (1937) reported abundant isolated *Symbos cavifrons* and *Bootherium bombifrons* crania from Lake Bonneville deposits, and McGuire (1980) reported *Euceratherium* from a Late Pleistocene deposit in central Nevada.

Kurten and Anderson (1980) described *Symbos cavifrons* as being taller and more slender than *Ovibos moschatus*, and this description matches the difference between the Crystal Ball Cave specimens and *Ovibos moschatus* perfectly. *Bootherium* is smaller than *Symbos* and is thought by many to represent females or juveniles of that genus (Kurten and Anderson 1980, Nelson and Madsen 1980). *Euceratherium* was larger and more heavily built than *Ovibos* (Kurten and Anderson 1980), and a first phalanx illustrated by McGuire (1980) is far too big at the distal end to match the second phalanges from Crystal Ball Cave. So, although no comparative material was available, both the description and known range of *Symbos cavifrons* make the Crystal Ball Cave specimens most referable to that species.

CONCLUSIONS

The Crystal Ball Cave assemblage is the first Late Wisconsinan fauna reported from the state of Utah and represents the closest known terrestrial fossil deposit to Lake Bonneville. The assemblage differs from most other cave faunas by its fossils being far inside the cave where man and birds probably had no influence on what was deposited. As a result, the assemblage is better than average in representing the proportions of animals that lived in the area, but there are some obvious biases. *Neotoma*, always an animal of low density, was the second most abundant genus in the assemblage simply because it is one of the

few animals that lives in the cave. But, other than cave-dwelling species, the assemblage probably gives a fairly good record of the abundance of most groups, at least those that lived in the immediate vicinity of the cave. The assemblage, for example, contains a ratio of small mammals to large mammals and carnivores to herbivores that might be expected in a living community. One very strong bias is the size of bones in the assemblage that I have attributed to the limit of bone size that a wood rat can carry. Bones of large mammals were brought in after the carcasses deteriorated, as evidenced by the presence of only small isolated elements. This bias tends to make large species less represented in the assemblage than in the living community and very large species unrepresented. Proboscidian fossils have been found in Lake Bonneville deposits (Nelson and Madsen 1980) but not in Crystal Ball Cave, probably because there was no means to transport such large bones inside.

It is difficult to say if any other animals besides wood rats contributed to transporting fossils into the cave. No other rodents are known to transport bones as wood rats do. Small carnivores could have done so, but the low abundance of carnivore fossils in the assemblage suggests that none habitually used the cave as a home. The small size of the original cave entrance would have prevented the entry of any large mammals. Both the distance of the fossils inside the cave and the low abundance of birds compared to mammals suggests that birds did not transport any fossils in, and this is one of the main differences between Crystal Ball Cave and Smith Creek Cave (and most other cave deposits). Clearly no inorganic processes such as wind, water, or gravity could have been responsible for the fossil deposits since they are in fine dust in an isolated part of the cave where none of these forces have a magnitude capable of transporting bones.

Crystal Ball Cave has been accumulating fossils from at least 23,000 years ago to the present. Although some of the fossils are Recent, the assemblage as a whole shows dramatic differences from the present-day local fauna. The poor representation of many mammals that currently live in the area may be due to the shift from *Neotoma cinerea* to *N. lepida* as the wood rat that inhabited the cave, and it

also suggests that the shift to the present climate occurred very recently in the history of the assemblage. *Brachyprotoma*, *Smilodon*, several species of *Equus*, *Camelops*, *Hemiauchenia*, and *Symbos* (or a closely related genus) are represented in the assemblage, all of which are now extinct. As mentioned earlier, there was a widespread extinction of large mammals at the close of the Pleistocene, the cause of which is under debate. This assemblage does not resolve that problem, but it does demonstrate that a marked climatic shift did take place contemporaneously with the extinctions, and this suggests to me that the extinctions were also a result of this climatic shift.

Equally as significant as the extinctions are the shifts in species ranges that the Crystal Ball Cave assemblage documents. The presence of *Ondatra zibethicus* and *Mustela cf. vison*, both of which require perennial water and are extirpated from the area, represent the drying of Lake Bonneville and perennial streams around Gandy Mountain. *Ochotona princeps* and *Martes americana* were extirpated from the Snake Range without replacement but still live at high elevations in nearby ranges. *Marmota flaviventris*, *Cervus elaphus*, and *Ovis canadensis* are represented in the assemblage but now inhabit only higher elevations in the Snake Range.

In other cases, species now abundant at Gandy Mountain are unrepresented or poorly represented in the assemblage, and their more boreal counterparts, now extirpated or rare in the area, are well represented as fossils. Among jackrabbits, *Lepus californicus* is presently the dominant species, but *L. townsendii*, its more boreal counterpart, is by far the better represented species in the fossil assemblage. Among cottontails, *Sylvilagus audubonii* and *S. nuttallii* make up the present local fauna, but only *S. nuttallii*, the more northern species, is found in the assemblage. *Lepus americanus*, a functional cottontail (J. A. White 1984, pers. comm.) and a very boreal animal, is probably represented but is now extirpated from the Snake Range. *Neotoma lepida*, the only wood rat seen living in Crystal Ball Cave, is rare in the assemblage, but *N. cinerea*, its more boreal counterpart, is one of the two most abundant fossil species. *Vulpes vulpes* is well represented in the cave

assemblage but extirpated from the area, and *Urocyon cinereoargenteus*, a more southern fox of similar size, now inhabits the area but is not found as a fossil.

Although the Crystal Ball Cave assemblage differs dramatically from the present-day local fauna, it is not atypical of Late Pleistocene assemblages in the region. Figure 9 shows the location of and Table 10 compares the mammalian taxa recovered from 10 Late Pleistocene-Recent cave assemblages within 400 km (240 miles) of Crystal Ball Cave. The most unique feature of the Crystal Ball Cave assemblage is the presence of *Brachyprotoma* since it represents the first citing of the genus from the western United States and the first recovery of the new species herein named *B. brevimala*. *Ondatra zibethicus* was found in Crystal Ball Cave but not at the other localities, probably because of this cave's close proximity to Lake Bonneville. *Symbos cavifrons* may be present at Crystal Ball Cave but absent from the other assemblages for the same reason since it is most common in Lake Bonneville deposits.

Some interesting paleoecological information can be inferred from the differences between the Smith Creek Cave and Crystal Ball Cave assemblages in particular since they are close geographically but located in somewhat different habitats. Several species of *Spermophilus* have been recovered from Smith Creek Cave, but large numbers of a single species have been recovered from Crystal Ball Cave. This can probably be attributed to the greater habitat diversity at Smith Creek Cave, which is at the base of a high mountain. Among camels, *Hemiauchenia* is better represented at Smith Creek Cave, but *Camelops* is better represented at Crystal Ball Cave. Although based on a small sample size, this suggests that *Hemiauchenia* favored higher and/or more rugged terrain than *Camelops* because Smith Creek Cave is located in the main Snake Range and Crystal Ball Cave is located in an outlier in Snake Valley. Of the non-camelid artiodactyls, *Odocoileus hemionus* is the best represented in the Crystal Ball Cave assemblage and *Ovis canadensis* is the best represented in the Smith Creek Cave assemblage. *Oreamnos harringtoni* fossils have been found in Smith Creek Cave but not in Crystal Ball Cave. Now *Antilocapra ameri-*

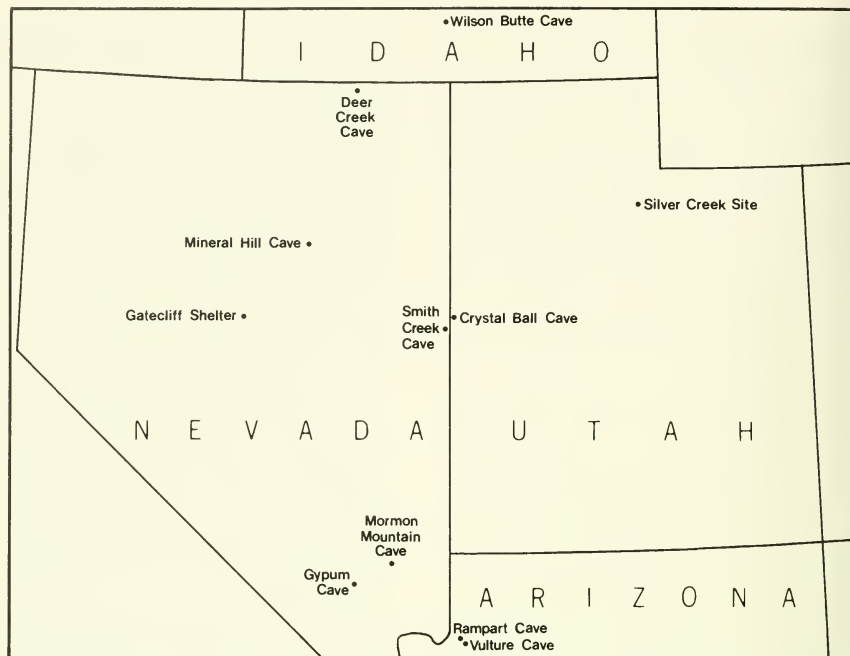


Fig. 9. Map showing the location of 10 Late Pleistocene cave faunas (see Table 10 for a list of the mammalian taxa recovered) and the Silver Creek fossil site described by Miller (1976).

TABLE 10. Comparison of the Crystal Ball Cave fauna with nine other Late Pleistocene/Early Holocene mammalian cave faunas located within 400 km (240 miles) of Crystal Ball Cave. The locations of these caves are shown in Figure 9.

- 1 Crystal Ball Cave, Utah (Heaton this report).
- 2 Wilson Butte Cave, Idaho (Gruhn 1961, Lundelius et al. 1983).
- 3 Deer Creek Cave, Nevada (Ziegler 1963).
- 4 Mineral Hill Cave, Nevada (McGuire 1980).
- 5 Gatecliff Shelter, Nevada (Grayson 1983, Thomas 1983).
- 6 Smith Creek Canyon caves, Nevada (Miller 1979, Mead et al. 1982).
- 7 Mormon Mountain Cave, Nevada (Jefferson 1982).
- 8 Gypsum Cave, Nevada (Mehring 1967, Lundelius et al. 1983).
- 9 Rampart Cave, Arizona (Harrington 1972, Lundelius et al. 1983).
- 10 Vulture Cave, Arizona (Mead and Phillips 1981).

Species/Localities	1	2	3	4	5	6	7	8	9	10
<i>Sorex</i> sp.	X				X	?				
<i>S. vagrans</i>					X					
<i>Notiosorex</i> sp.							X			X
<i>N. crawfordi</i>							X			X
<i>Myotis</i> sp.	X						X			
<i>Eptesicus fuscus</i>							X			
<i>Plecotus townsendii</i>	?						X			
<i>Antrozous pallidus</i>	X					cf.	X			
<i>Nothrotherium</i>								X	X	
<i>N. shastensis</i>								X	X	
<i>Ochotona princeps</i>	X	X	X	X	X	X	X			
<i>Sylvilagus</i> sp.	X	X	X	X	X	X	X	X	X	
<i>S. idahoensis</i>	X	X	X		X	X				

TABLE 10 continued.

Species/Localities	1	2	3	4	5	6	7	8	9	10
<i>S. nuttallii</i>	X	X			X		X			
<i>Lepus</i> sp.	X	X	X	X	X	X		X	X	
<i>L. americanus</i>	cf.									
<i>L. townsendii</i>	X				cf.					
<i>L. californicus</i>	X	X			cf.	cf.			cf.	
<i>Marmota</i> sp.	X	X	X	X	X	X	X		X	X
<i>M. flaviventris</i>	X	X	X	X	X	X	X		X	cf.
<i>Spermophilus</i> sp.	X	X	X	X	X	X	X		X	X
<i>S. armatus</i>		X								
<i>S. townsendii</i>	X	X			X	cf.				
<i>S. richardsonii</i>		X				cf.				
<i>S. beldingi</i>		X			X	cf.				
<i>S. variegatus</i>						X	X			
<i>S. lateralis</i>						cf.				X
<i>Anmospermophilus leucurus</i>	cf.				X	cf.	X			
<i>Eutamias</i> sp.	X	X		X	X	X	X			cf.
<i>E. minimus</i>	X	X			X	X				
<i>E. umbrinus</i>					X	cf.				
<i>E. dorsalis</i>	X				X		cf.			
<i>E. amoenus</i>							X			
<i>Thomomys</i> sp.	X	X	X	X	X	X				
<i>T. talpoides</i>		X				cf.				
<i>T. umbrinus</i>	X				X					
<i>Perognathus</i> sp.	X				X	X	X			
<i>P. parvus</i>					X	cf.	X			
<i>P. formosus</i>	cf.									
<i>P. intermedius</i>										cf.
<i>Microdipodops</i> sp.	X				X	X				
<i>M. megacephalus</i>	X				X	cf.				
<i>Dipodomys</i> sp.	X				X	X				X
<i>D. ordii</i>						cf.				
<i>D. microps</i>	X									
<i>Castor canadensis</i>			X							
<i>Reithronomys</i> sp.							X			
<i>R. megalotus</i>							X			
<i>Peromyscus</i> sp.	X	X		X	X	X	X			X
<i>P. maniculatus</i>	X	X					X			
<i>P. crinitus</i>	cf.				X					
<i>P. truei</i>	cf.						X			
<i>Onychomys</i> sp.					X					
<i>Neotoma</i> sp.	X	X	X	X	X	X			X	X
<i>N. lepida</i>	X				X	X				
<i>N. cinerea</i>	X	X	X		X	X				
<i>Ondatra</i> sp.	X									
<i>O. zibethicus</i>	X									
<i>Clethrionomys</i> sp.		X								
<i>C. gapperi</i>		X								
<i>Phenacomys</i> sp.		X			X	X				
<i>P. intermedius</i>		X			cf.	cf.				
<i>Microtus</i> sp.	X	X		X	X	X	X		X	X
<i>M. californicus</i>									X	
<i>M. longicaudus</i>	cf.	X			cf.	cf.	cf.			
<i>M. montanus</i>	cf.	X			cf.	cf.				
<i>M. pennsylvanicus</i>	cf.									
<i>Lagurus curtatus</i>	X	X								
<i>Zapus princeps</i>					cf.					
<i>Erethizon dorsatum</i>			X		X	X				X
<i>Canis</i> sp.	X		X		X	X		X		
<i>C. familiaris</i>			X							
<i>C. latrans</i>	cf.			X	X	cf.				
<i>C. lupus</i>	cf.		X			cf.				
<i>Vulpes</i> sp.	X	X		X	X	X		X		

TABLE 10 continued.

Species/Localities	1	2	3	4	5	6	7	8	9	10
<i>V. vulpes</i>	X				X	X				
<i>V. velox</i>	X					X		X		
<i>Urocyon</i> sp.				X						
<i>Ursus</i> sp.			X			X				
<i>U. horribilis</i>			X							
<i>Bassariscus</i> sp.						X			X	X
<i>B. astutus</i>						X				X
<i>Mustela</i> sp.	X	X		X		X		X		
<i>M. erminea</i>		X				X				
<i>M. frenata</i>	cf.	X				X				
<i>M. vison</i>	cf.					X				
<i>Martes</i> sp.	X	X	X			X				
<i>M. americana</i>	X	X	X							
<i>M. nobilis</i>						X				
<i>Taxidea taxus</i>				X		X				
<i>Spilogale</i> sp.		X		X	X	X				
<i>S. putorius</i>		X			X					
<i>Mephitis mephitis</i>					X					
<i>Brachyprotoma</i> sp.	X									
<i>B. brevinata</i>	X									
<i>Smilodon fatalis</i>	cf.									
<i>Panthera atrox</i>						?				
<i>P. onca</i>						X				
<i>Felis concolor</i>	X					X	X		X	
<i>Lynx</i> sp.	X		X	X	X	X			X	X
<i>L. rufus</i>	cf.		X		X	X		X	X	
<i>Equus</i> sp.	X	X		X		X		X	X	
<i>E. sp. (large)</i>	X					X				
<i>E. scotti</i>	cf.									
<i>E. occidentalis</i>								X		
<i>E. sp. (small)</i>	X					X				
<i>E. conversidens</i>	?									
<i>Camelops</i> sp.	X	X				X		X		
<i>C. hesternus</i>	cf.					X				cf.
<i>Hemiauchenia</i> sp.	X	X		X		?		X		
<i>H. macrocephala</i>	cf.									
<i>Cervus</i> sp.	cf.		?		X	X				
<i>C. claphus</i>	cf.				X	X				
<i>Odocoileus</i> sp.	X		X			X		X		X
<i>O. hemionus</i>	X							X		
<i>Antilocapra</i> sp.	X		X	X	X	X				X
<i>A. americana</i>	X		X		X	X				X
<i>Capromeryx minor</i>						?				
<i>Oreamnos</i> sp.						X			X	
<i>O. harringtoni</i>						X			X	
<i>O. americanus</i>						cf.				
<i>Ovis</i> sp.	X		X	X	X	X	X	X	X	X
<i>O. canadensis</i>	X		X	X	X	X	X	X	X	X
<i>O. aries</i>	cf.					cf.				
<i>Bison</i> sp.		X	?		X	?				
<i>B. bison</i>					X					
<i>Eucerotherium</i> sp.				X						
<i>Symbos cavifrons</i>	cf.									

cana is the best represented artiodactyl in Snake Valley, *Odocoileus hemionus* is the best represented artiodactyl in the Snake Range, *Ovis canadensis* is found only at high elevations in the Snake Range, and *Oreamnos harringtoni* is extinct. This suggests that these

four artiodactyls can be placed in the following order of elevation preference starting at the highest: *Oreamnos harringtoni*, *Ovis canadensis*, *Odocoileus hemionus*, and *Antilocapra americana*. At the end of the Pleistocene, in rough terms, each of these species

moved upward in elevation to fill the habitat of the next higher species. The one at the top went extinct; the one at the bottom became abundant. Differences of lesser magnitude between the Crystal Ball Cave and Smith Creek Cave assemblages must be dealt with more carefully because they may represent slight differences in the age of the deposits, biases in the mode of deposition, human intervention, or chance preservation. Identification of more material, especially at Smith Creek Cave, could make comparison of these two assemblages a very valuable paleoecological study.

The Crystal Ball Cave fauna, like many previously studied faunas, shows that a dramatic climatic shift occurred at the end of the Pleistocene and caused many species to move northward in latitude and upward in elevation and to become extinct. This shift is particularly well expressed in the Crystal Ball Cave assemblage because its close proximity to Lake Bonneville made the drying trend very severe in the area. The Crystal Ball Cave fauna documents the previous ranges and abundances of many taxa that help in reconstruction of details of the last Pleistocene ice age.

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